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Agricultural
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Service

Northern
Plains Area

Natural Resources Research Center

1992 Report

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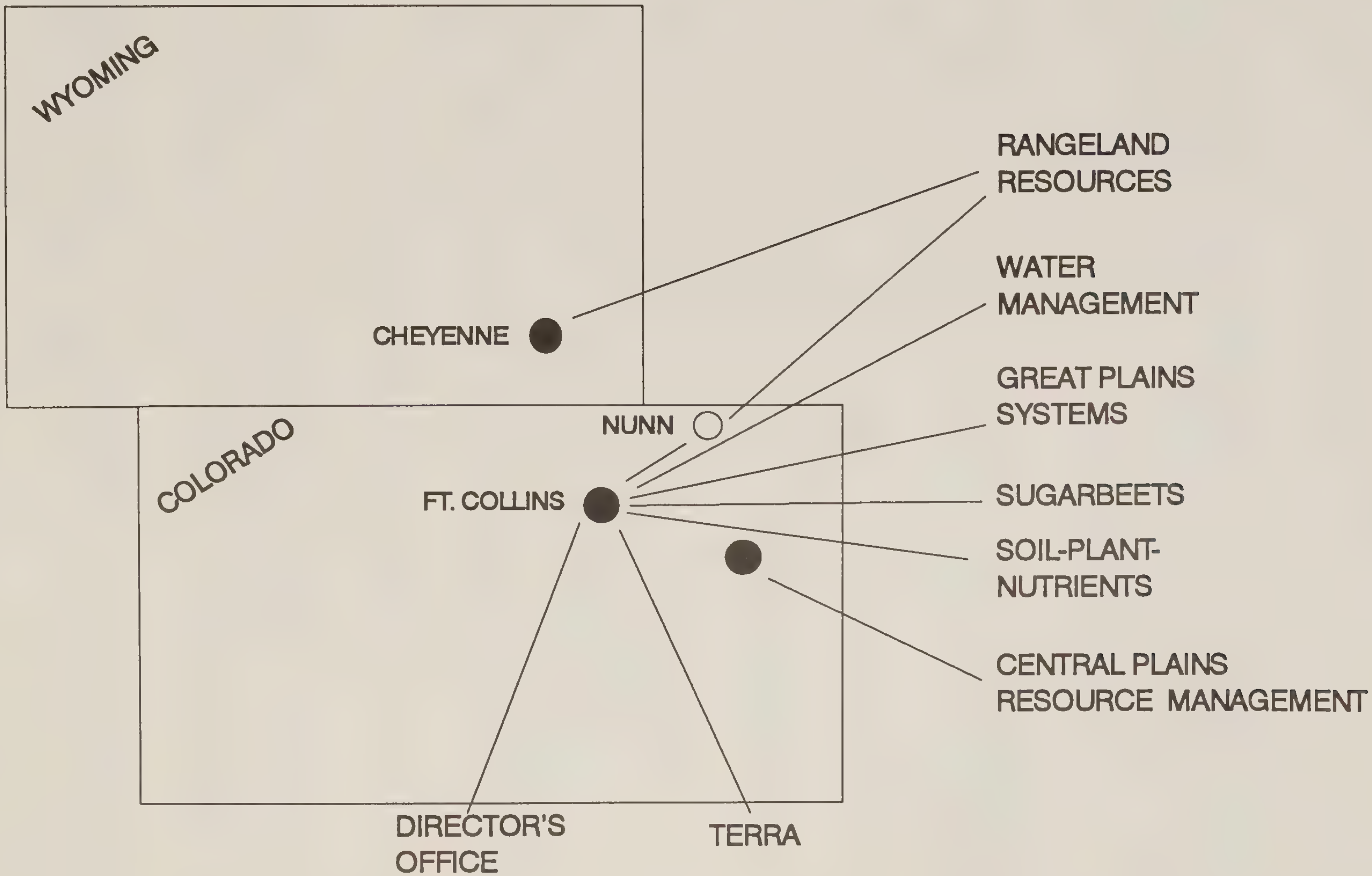

EXECUTIVE SUMMARY

James R. Welsh

The Natural Resources Research Center grew from an organization under formation to one of coordinated activity among units and programs. Information contained in this report clearly demonstrates the high productivity level of individual scientists and staff members, research units and the Center in general. Output is reflected in high levels of publications, awards and recognitions, public presentations and involvement in technology transfer partnerships.

More importantly, all NRRC units are actively engaged in research addressing important issues for agriculture in the 21st century. Clearly, agriculture must increase it's awareness of and interaction with the environmental community to survive and thrive. Examples of NRRC unit research areas addressing contemporary and futuristic societal needs include:

- Alternative cropping opportunities and methods for improved economic return while protecting the environment.
- Computer based systems analyses to aid in management decisions.
- Ground water quality as affected by agricultural practices.
- Agricultural chemical fate and transport.
- Efficient economical irrigation management.
- Residue management to reduce erosion, aid in cropping system.
- Alternatives and efficiently manage natural precipitation.
- Rangeland strategies to maximize forage production.
- Efficient and environmentally safe control mechanisms for sugarbeet pests.
- Economically sound weed control practices which reduce chemical use
- Agricultural production systems as sources and sinks for factors impacting global climate change.

These and many other ongoing NRRC research activities contribute in a coordinated fashion to future food and fibre needs of our society.

The NRRC has mounted an aggressive program to improve product quality and work closely with the research customer. Partnerships are being developed with a broad spectrum of customers. Needs and expectations are being identified. Mechanisms are being developed to transfer research based information to the customer in a highly user friendly fashion.

We look to the challenges ahead with excitement and anticipation. As an aggressive futuristic research organization, the NRRC stands ready to meet the needs of society well into the next century.

NRRC Staff - 1992

James Welsh, Center Director
Olga Lee, Secretary
Ernest Affa, Facilities Manager

	Central Plains Resources Management Research Unit	Great Plains Systems Research Unit	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Terrestrial Ecosystems Regional Research and Analysis	Water Management Research Unit
Research Scientists	Ardell Halvorson, RL Randy Anderson Rudy Bowman Steven Hinkle David Nielsen Merle Vigil	Lajpat Ahuja, RL Carlos Alonso Vernon Cole Jon Hanson Gregory McMaster Marvin Shaffer	Gerald Schuman, RL Terrence Booth Gary Frasier Richard Hart Jack Morgan Charley Townsend	Ronald Follett, RL William Hunter Gordon Hutchinson Arvin Mosier Lynn Porter	Earl Ruppel, RL Susan Martin Leonard Panella	Donn Decoursey	Dale Heermann, RL Walter Bausch Gerald Buchleiter Harold Duke Gordon Kruse Edward Schweizer Roger Smith
Support Scientists	Bill Beard Curt Reule	Patricia Bartling Mary Brodahl Gale Dunn Virginia Ferreira Harriet Rector	Daniel LeCain Jean Reeder Ernest Taylor	Robert Lober William O'Dean			Richard Miskimins Kristine Stahl Paul Williams
Post Docs		Robert Aiken Barry Baker Joseph Benjamin Romelito Lapitan Bruce Wylie	Andrew Lenssen John Reed	Jorge Delgado			Lori Wiles
Research Support Staff	Robert Florian Donna Fritzler Herman Horner Hubert Lagae Arnold Page Gene Uhler	William Dailey Debora Edmunds Jo Foy Steve Huffman Terry Leonard Michael Murphy Daniel Palic Kenneth Rojas Lucretia Sherrod	Willard Ackerman Mary Ashby George Chavez Stanley Clapp Pamela Freeman Larry Griffith Jan Hagen Jennifer Keiser Roger Kerbs Chris Mahelona Matt Mortenson Dennis Mueller James Pry Kenneth Scott Jeffrey Thomas Barry Weaver	Charles Andre Edward Buenger Susan Crookall Cathy Krumwiede Margarita Licha Robin Montenieri Elizabeth Pruessner Mary Smith	Christina Andre Mary McClintock Patricia Mustain Les Shader Johnny Thomas John Vasquez Bradley Wickham	Jeff Miller	Timothy Barker Douglas Barlin Carley Berg Theodore Bernard Michael Blue Brad Carnahan Mark Collins Christopher Hay Jonathan Jordan Timothy Knorr Brian Neubauer Darren Salvador
Administrative Support Staff	Virginia Allen Linda Pieper Llewellyn Bass	Virginia Krug Marlene Miller Monique Wilson	Ann Flores Pam Jordan Kathleen Peterson	Stacey Wilkins	Marcella Currie-Gross		Mai Dailey Maxine McCauley
Visiting Scientists/ Others	Wayne Shawcroft Scott Armstrong Mike Koch	Ma Qingli Soren Hansen	J. Reed Cockrell R.L. Latterell	John Doran Eldor Paul			

AWARDS AND RECOGNITION - 1992

Employee	Award(s)/Recognition Received
Lajpat Ahuja	• Associate Editor SSSA, Division S-1 • ASA Organization, Policy and By-Laws Committee
Charles Andre	• Certificate of Appreciation for researching and organizing the installation of the new telephone system as the Federal Building
Douglass Barlin	• Certificate of Merit (cash award) for sustained superior performance between April 1991 and March 1992
Pat Bartling	• USDA Distinguished Service Award (Group - NLEAP) • Certificate of Merit for sustained outstanding performance in the development of the nitrate leaching and economic analysis package (NLEAP) databases
Terrence Booth	• Secretary: W-168 Seed Quality Investigations
Mary Brodahl	• USDA Distinguished Service Award (Group - NLEAP) • SCS Certificate of Appreciation
Stanley Clapp	• Certificate of Merit (cash award) for exemplary service to the grazing management research
William Dailey	• Certificate of Merit (cash award) for renovating and maintaining the computer system and network of the Great Plains Systems Research Unit
Virginia Ferreira	• Vice-Chair ASAE Precipitation and Runoff Committee • Appointed to ARS-SCS Curve Number Work Group • NPA Outreach Award
Ann Flores	• Certificate of Merit (cash award) for exemplary service to the Unit
Ronald Follett	• USDA Distinguished Service Award - (Group - NLEAP) • SWCS Fellow • Certificate of Appreciation - SCS • Certificate of Appreciaiton - SWCS
Gary Frasier	• Continuing: Editor: Journal of Range Management Editor: Rangelands
Ardell Halvorson	• USDA Distinguished Service Award (Group - NLEAP) • Chapter Commendation Award from Colorado Chapter of SWCS

Employee	Award(s)/Recognition Received
Jon Hanson	• Remote Sensing and GIS Committee, SRM • Program Committee, Annual Meeting, SRM
Richard Hart	• W.R. Chapline Research Award - SRM Publications Committee - SRM
Roger Kerbs	• Certificate of Merit (cash award) for exemplary service to Central Plains Experimental Range
Olga Lee	• Certificate of Merit (cash award) for organizing and coordinating a Center-wide TQM seminar • Certificate of Merit (cash award) for editing 1991 NRRC Progress Report
Susan Martin	• Continute 2-yr appointment (91-93) as Editor-in-Chief of J. of Sugar Beet Research • Elected as Chair-Elect (92-93), Phytochemical Section, Botanical Soc. of America • Taught the Physiology Section of the first Beet Sugar Agricultural School (BSDF), July 1992 • Nominated for Vice President (=President Elect) of the American Society of Sugar Beet Technologists
Mary McClintock	• Location Safety Performer of the Year, 1992
Jack Morgan	• Editorial Board: Journal of Field Crop Research
Mike Murphy	• Unit Certificate of Appreciation for researching and organizing the installation of the new phone system in the Federal Building
Patricia Mustain	• Certificate of Merit (cash award) for consistent excellence in performance of duties as a Biological Technician in the Sugarbeet Research Unit
David Nielsen	• Certificate of Merit (cash award) for editing 1991 Unit Progress Report
Kathleen Peterson	• Certificate of Merit (cash award) for outstanding administartive service to the Unit
John Read	• Appointed: ACS824-Forage, Grassland and Rangeland • Resource Committee - American Society of Agronomy
Earl Ruppel	• Fellow Award, American Phytopathological Society, August 1992 • Taught the Sugarbeet Disease section in the first Beet Sugar Agricultural School of the Beet Sugar Development Foundation, July 1992

Employee	Award(s)/Recognition Received
Gerald Schuman	• Editorial Board: Journal of Soil & Water Conservation • Elected: President, American Society of Surface Mining & Reclamation • Certificate of Merit (cash award) for exemplary service to Central Plains Experimental Range
Edward Schweizer	• Recipient of the 1992 Weed Science Society of America Outstanding Research Award • Recipient of the 1992 Weed Science Society of America Award of Excellence as coauthor of the outstanding paper published in *Weed Science*, 38:436-444. 1990
Marvin Shaffer	• 1992 NPA Scientist of the Year • USDA Distinguished Service Award (Group Leader - NLEAP) • SCS Certificate of Appreciation • ARS Rep on Sustainable Ag, Project Monitoring and Analysis Work Group, CCWCD
Jeffrey Thomas	• Certificate of Merit (cash award) for exemplary service to Central Plains Experimental Range
Charley Townsend	• ARS representative: National Certified Miscellaneous Legume Variety Review Board • Member: Other Legumes Subcommittee of Crop Registration • Committee: Crop Science of America • Certificate of Merit (cash award) for completing "Changes is Vegetation and Land Use in Eastern Colorado: upon the completion of author
Stacey Wilkins	• Certificate of Merit (cash award) for sustained superior performance and initiative as Secretary for the Unit

PROGRESS REPORTS

NATURAL RESOURCES RESEARCH CENTER

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MISSION STATEMENT

Deliver a coordinated research program providing scientifically sound information to improve agriculture systems regionally and nationally.

NRRC PROGRESS REPORT

James R. Welsh
Natural Resources Research Center

NRRC COORDINATION: The NRRC unit Research Leaders serve as the Board of Directors for the Center. The Board meets monthly and considers issues and programs to be acted upon through coordinated efforts. The following items constitute NRRC projects and activities for 1992.

TRAINING PROGRAMS: Training was identified as a major project to be developed through the Center. A training room was designed and equipped with state-of-the-art computers and projection equipment in conjunction with remodeling and space expansion in the Federal Building. The facility will be used for program related training such as NLEAP and subject matter training such as SAS and RMIS.

The Center surveyed staff to determine top priority needs and provided leadership in developing trainers and resources to meet these needs. The Board recommended that a top priority program should be Total Quality Management for all Center personnel. Plans were developed to utilize STEP Associates in training workshops on TQM principles, team building and tools to be held in early 1993. The goal is to have all personnel trained and TQM initiated in every unit in 1993.

CUSTOMER INTERACTION: Customer identification and interaction received serious attention during 1992. In keeping with TQM principles, all units in the Center moved toward more specific awareness of customer needs. Liaison and advisory groups, action agencies, other research programs, individual agricultural producers, and environmentally oriented organizations were targeted as important and concerned customers. This topic will receive increased attention in 1993, particularly as TQM is implemented.

TECHNOLOGY TRANSFER: The NRRC signed and implemented a Memorandum of Understanding with the SCS and the Colorado Association of Conservation Districts whereby meetings will be held periodically to identify field based priority research needs. The NRRC will determine which high priority items can be addressed with present resources and provide research based answers as quickly as possible. The joint committee met twice in 1992, identified priority research issues and initiated programs to produce science based answers. This program will be continued as a valuable mechanism to serve agricultures needs.

The NRRC has participated with the Water Management unit in developing a model partnership program with the irrigation industry. As a result of a series of leadership committee meetings with industry representatives, several important results have been achieved. First, the Irrigation Association has established a formal mechanism to identify high priority research needs and communicate these needs to ARS. Second, through joint ARS/Industry sponsorship a National Academy of Science study will be conducted on the future of irrigation in the US. The study will be funded in part by the Irrigation Association. Third, a directory is now available to industry summarizing the ARS irrigation research program with scientist contact information. Finally, preliminary plans have been laid to have

industry representatives visit the Water Management unit, receive an informational overview and supply researchers with suggestions for future research directions.

The NRRC, in close partnership with the Great Plains Systems Research unit, has provided leadership in developing the Great Plains Agrisystems Project with the goal of a scientifically based decision support system for agriculture producers and technology transfer specialists. The project, under the guidance of a broad based steering committee, will also be producing scientific information, conducting workshops and publishing documents related to DSS development and use. Initial prototypes will be developed and tested in 1993, using agricultural producers as the beta testers.

The Plant-Soil-Nutrient Research Unit is a major contributor to the N-management technology transfer package by editing and publishing the book entitled "N-Management for Ground Water Quality and Farm Profitability", providing training slides, presenting training for a 2-hour video, developing a nomograph for a manual solution to the "Nitrate Leaching equation", and developing a list of selected questions and answers about N-management. In addition, a USDA material transfer agreement was issued allowing Urbana Labs (a large commercial supplier of legume inoculants) to evaluate the nitrogen-fixing ability of the patented *Bradyrhizobium japonicum* NOD^+ mutant.

TECHNOLOGY RESOURCES INTEGRATED MANAGEMENT (TRIM): An NRRC supported project designed to provide producers with indepth research information as an aid in making management decisions. The TRIM Board is made up of ARS research personnel, CSU research and extension staff, financial experts and farm management educators. The program is coordinated and managed by a facilitator employed by the Logan County Extension Service. The Central Plains Resources Management Research Unit plays a key role in TRIM program development. To date five producer cooperators have signed agreements with the program and have established short and long term goals for their operations. They have agreed to serve as the initial beta testers for the GPAP decision support system project. Approximately five additional cooperators will be secured in 1993.

TERRESTRIAL ECOSYSTEM REGIONAL ANALYSIS (TERRA): This program activity has grown into a valuable laboratory offering state-of-the-art opportunities for model stimulation and interaction between atmospheric and terrestrial components of global change. TERRA is proving to be a highly useful resource for agricultural research programs by providing leadership in electronically supported decision making, modular model development and complex data base management.

ECONOMIC ANALYSIS PROJECT: An agricultural economist has been contracted to conduct economic analysis on summerfallow practices including conventional, minimum till and no-till. Analyses are also being initiated on alternate cropping systems under dryland production based on the Central Plains Resources Management Research Unit and Colorado State University generated data. Results will be utilized in decision support systems and other technology transfer activities.

PROGRAM REVIEWS: The NRRC Director served as facilitator for an extensive area and national range program review and planning exercise. The process resulted in the establishment of priority issues and an action plan to address these issues.

The research program in each NRRC unit was reviewed as an aid in establishing appropriate mission statements and program goals and objectives. All staff within each unit participated in the review process. The review was particularly helpful in making personnel sensitive to customer needs, emphasizing the value of ongoing dialog regarding unit direction, and identifying opportunities for intra-unit cooperative research.

FACILITIES AND EQUIPMENT: Significant progress is underway in improving the heating/ventilating/air conditioning system in the Federal Building housing the Soil-Plant-Nutrient unit. This project will be completed in 1993. The unit is also installing new chillers to completely update their constant temperature rooms.

Additional space has been obtained for the Great Plains Systems Research Unit in the Federal Building and remodeling is underway. The training room will be incorporated into this area.

The slidemaker and scanner have proven to be valuable high-use NRRC-wide equipment items.

PUBLIC INTERACTION: The NRRC provides an important link to other agencies and organizations. These include the Great Plains Agriculture Council, Colorado State University, the Sustainable Agriculture program, the Colorado Department of Agriculture, the Soil Conservation Service, the Irrigation Association and the Federal Initiative for Public\Private partnership. The NRRC represents all unit programs in these contacts and actively solicits, on a continuing basis, input and advice on program priorities and direction.

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

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MISSION STATEMENT

The mission of the Central Plains Resources Management Research Unit is to enhance the economic and environmental well-being of agriculture by development of integrated cropping systems and technologies for maximum utilization of soil and water resources. Emphasis is on efficient use of plant nutrients, pesticides, and water and soil conservation/preservation.

POPULATION THRESHOLDS FOR JOINTED GOATGRASS AND VOLUNTEER RYE IN WINTER WHEAT

R.L. Anderson, D.J. Lyon, G.A. Wicks, S.D. Miller, and P. Westra
USDA-ARS, Univ. NE, Univ. WY, and CSU
Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00-D

PROBLEM: Jointed goatgrass and volunteer rye infest winter wheat in the Central Great Plains, resulting in significant yield losses. Extensive herbicide screening research is being conducted in this region to find suitable herbicides for controlling these species in winter wheat. Also, developing a winter wheat cultivar tolerant to herbicides active on grass weeds is being explored. If this research thrust is successful, it would be appropriate to know the economic threshold for each species so that producers can determine when to use herbicides. Research exploring the use of mowing for reducing the future soil seed bank has also demonstrated the effectiveness of this control strategy. The threshold equations also could be used to guide management decisions with this control practice.

The objective of this study is to develop yield loss regression equations based on plant population for jointed goatgrass and volunteer rye in winter wheat.

APPROACH: This study was established in winter wheat following the conventional practices for the region of each cooperator. At the Akron site, Tam 107 was planted at 45 kg/ha with a hoe-drill in 30 cm row spacing. The planting date was Sep. 18, and nitrogen was applied at 65 kg/ha after planting. The site was in a stubble mulch fallow system, where sweep plowing and rod-weeding controlled weeds during fallow. The soil type is a Rago silt loam.

Jointed goatgrass and volunteer rye was broadcast in separate plots at 5, 10, 25, and 50 plants/m^2 and incorporated with the mulch treader before planting wheat. Initial plot size was 3 m by 3 m. During the spring, two 1 m by 1 m subplots will be designated for treatment analysis. The experimental design is a randomized complete block with 4 replications.

Data goals include: 1) approximate date of weed emergence in relation to winter wheat emergence; 2) weed density counts 6 weeks after planting and before April 1; 3) date of flowering for winter wheat, jointed goatgrass, and volunteer rye; 4) winter wheat grain yields from the two subplots; 5) weed seed contribution to dockage and seed bank population from 1 subplot; and 6) individual plant seed production by weed species (select up to 6 plants per subplot) to supply data for modelers in determining the economic optimal threshold level. Weather data collected will include monthly rainfall during the study and long-term average for each site.

Yield loss data will be used to develop regional regression equations for predicting the economic population threshold for each species.

FINDINGS: The study was established. At Akron, limited emergence occurred, especially with jointed goatgrass. Hopefully, more emergence will occur over winter and allow establishment of subplots with various population levels.

INTERPRETATION: Study has just been established and no data has been collected.

FUTURE PLANS: At conclusion of this study, a regional publication will be developed to guide producer decisions in controlling these species.

EFFECT OF CROPPING ROTATIONS AND TILLAGE ON EMERGENCE OF JOINTED GOATGRASS AND DOWNY BROME

R.L. Anderson and D.C. Nielsen
Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00-D

PROBLEM: In the Plains region, jointed goatgrass and downy brome are two difficult-to-control weeds infesting winter wheat with viable seed persisting in soil for up to five years. Rotations which include spring-planted crops lengthen the time between winter wheat crops. This allows the producers to minimize interference of jointed goatgrass and downy brome infestation within winter wheat. The weed seed population decreases in soil because the weed seed germinates or decays naturally before the winter wheat is planted. Success in reducing the weed seed population would be enhanced if producers could hasten germination of weed seeds in the soil during non-wheat years.
The choice of spring-planted crop may also affect the germination of these winter annual weeds in the fall of the crop season. For example, proso millet and sorghum canopies greatly inhibit volunteer winter wheat emergence. However, emergence within a corn canopy is not reduced to the same extent, indicating that the use of corn rather than proso millet or sorghum in the rotation may increase the rate of weed seed decline by germination. Wheat residues on the soil surface also increase the germination in all canopies, thus, a no-till system may enhance second-fall germination of these grass weeds. If spring-planted crop canopies affect germination of jointed goatgrass and downy brome, then producers can target their severely-infested sites for germination-enhancing canopies. Also, combining one timely tillage operation (to stimulate germination yet not bury the residue) with a selected crop canopy may greatly enhance weed seed germination without deleteriously affecting crop growth.
The objectives for this study are: 1) evaluate the effect of crop rotations and tillage on the longevity of jointed goatgrass and downy brome seed in the soil; 2) determine the effect of summer-annual crop canopies on fall emergence of jointed goatgrass and downy brome; and 3) correlate the emergence of jointed goatgrass and downy brome with soil temperature and moisture levels and develop a predictive model.

APPROACH: Four crop canopy choices are being evaluated within 3-, 4-, and 5-year rotations. The rotations are wheat-canopy choices-fallow, wheat-corn-canopy choices-fallow, and wheat-corn-oats for forage-canopy choices-fallow. Two tillage systems are being compared: no-till and reduced till (one sweep plow operation in the fall). The canopy and tillage treatments are arranged as a two-way factorial in a randomized complete block design with three replications. The rotations are arranged in a split-block design. Within each plot, 1 m^2 was designated and 200 seeds each of jointed goatgrass and downy brome spread on the soil surface. The tillage operation occurred after seed spreading. Winter wheat is present within the local soil seed bank, but jointed goatgrass and downy brome had not been observed previously at this site. Seedling emergence is being recorded weekly for each 1 m^2 site for the duration of the study (5 years). There are 24 sites for each rotation (3 replications for each of the 4 canopies and 2 tillage treatments) and 3 rotations, resulting in 72 sites. After

completion of the canopy choice cropping season within each rotation, winter wheat will be planted the following September. Weed seedling counts will also be recorded for each of the 24 sites from the previous 4 canopies and 2 tillage systems within the wheat crop. Soil samples will be collected from each site after wheat harvest to estimate the remaining weed seed population.

Within each canopy in 1992, 25 seeds of each species was planted in one meter rows. Simulated rainfall at 6 mm was applied after planting. Seedling counts were recorded 21 days later. Planting dates were Aug. 15, Sep. 1, Sep. 15, Oct. 1, Oct. 15, and Nov. 1.

Soil temperature is being monitored continuously with thermocouple arrays at 2.5 cm. Soil water levels are being determined daily by Time Domain Reflectometry for the top 5 cm. Standard weed control practices are being followed for each crop.

FINDINGS: Crop canopy microclimate affected the emergence of jointed goatgrass and downy brome. For every seedling (of either species) emerging in proso millet, 4 emerged in corn, barley, and fallow. These results are similar to previous research which showed that corn was conducive for fall emergence whereas proso millet reduced emergence. Barley offers another option for producers in devising alternative crop rotations for controlling jointed goatgrass and downy brome.

Emergence of jointed goatgrass and downy brome is controlled by both surface soil water content and surface soil temperature. Emergence occurs when the average soil moisture is greater than 10% volumetric water content for the weed prior to emergence, and average soil temperature is less than 20 C.

Average grain yields for corn and proso millet were 3480 kg/ha (55 bu/ac) and 2770 kg/ha (44 bu/ac), respectively. These are crop yields after 3 years of cropping, (winter wheat in 1990, corn in 1991, and canopies in 1992). Precipitation during the duration of this study (1990-present) has been slightly below normal. These results demonstrate the potential for increasing cropping intensity in this region. Barley was hailed out before harvest.

INTERPRETATION: If jointed goatgrass and downy brome are present in a field, producers should sweep plow once after winter wheat harvest to enhance seedling emergence and reduce the soil seed bank population. If a producer follows an alternative rotation scheme for winter annual grass control, corn or barley should be the first crop grown after winter wheat. Proso millet imposes a microclimate that is not conducive for germination and emergence of either jointed goatgrass or downy brome. Therefore, producers should target proso millet for fields that are not infested with winter annual grass weeds.

FUTURE PLANS: Data will be collected for the duration of this study and published after statistical analysis. The limits of soil temperature and moisture controlling weed emergence will be studies in more detail to develop an emergence model.

CLOMAZONE (COMMAND) FOR CONTROL OF JOINTED GOATGRASS AND DOWNY BROME IN WINTER WHEAT

R.L. Anderson, C.G. Ross, and S.D Miller
USDA-ARS, FMC, and Univ. WY
Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00-D

PROBLEM: Jointed goatgrass and downy brome are severe weed problems in the winter wheat production area of the Great Plains region. Due to similar genetic and growth characteristics as winter wheat, herbicide options for within-crop control of these species are very limited. In the Pacific Northwest, in-wheat applications of atrazine have been successful in controlling downy brome in winter wheat. Clomazone also shows potential for controlling both jointed goatgrass and downy brome with in-wheat applications, but phytotoxicity to winter wheat has occurred in some situations. The focus of this research is to explain why this phytotoxicity to winter wheat occurs in relation to cultural practices available to the producer and to identify the physical factors which will enhance clomazone bioactivity on jointed goatgrass and downy brome without injuring winter wheat. Specific objectives are: 1) determine the sensitivity of jointed goatgrass, downy brome, and winter wheat to clomazone in soil; 2) examine the effect of phorate (Thimet) on safening wheat to clomazone; and 3) determine the effect of precipitation timing and amount and growth stage on species response to clomazone. This study is comprised of field and greenhouse trials.

APPROACH: Greenhouse study: Sensitivity of jointed goatgrass, downy brome, and two winter wheat varieties (Tam 107 and Lamar) to five concentrations of clomazone (5, 10, 20, 30, and 40 ng a.i./mg) were determined in a silt loam and a sand soil. Eight seeds of each species were planted in treated soil and % chlorosis and above-ground biomass of all seedlings were determined 21 days after emergence for each species. The soil was maintained at 80% field capacity by daily watering to the soil surface, with the pots being weighed to determine the water level. The experimental design was a randomized complete block with 6 replications. Six seeds of each of the above species and varieties were planted at 0, 1, 2, 3, 4, and 5 cm below the soil surface in the silt loam. Clomazone at 0.28 kg/ha was applied to the soil surface, then water at simulated rainfall levels of 8 mm was applied to the clomazone-treated surface. After the initial watering treatment was applied, the pots were covered with tin foil for 4 days (allowing the seedlings to emerge), then water levels were maintained at 80% field capacity by daily weighing and sub-irrigating. Percent chlorosis and biomass measurements of all seedlings were taken 21 days after emergence.

Field study: Clomazone at 0.14, 0.28, and 0.56 kg/ha was applied at three times: preplant, preemergence, and postemergence (1-3 leaf stage) to 'Sandy' and 'Tam 107' winter wheat. Phorate at 6.8 g/1000 m of row was applied to half of each plot with the seed at planting. The site was located on a Weld silt loam. Six weeks after wheat emergence, % chlorosis was assessed. Grain yield, biomass production, and yield components were determined at harvest. The experimental design was a factorial with clomazone rate and time of application as the main

factors, while phorate application was arranged as a split block. There were 4 replications. The varieties were planted adjacent to each other.

FINDINGS: Greenhouse studies. In all greenhouse trials, downy brome was more sensitive to clomazone than jointed goatgrass. This observation agrees with field studies conducted by other scientists in that jointed goatgrass control by clomazone is marginal. Stage of growth and timing of precipitation affects clomazone effectiveness on downy brome and jointed goatgrass. Bioactivity was highest when clomazone was applied before water imbibition occurred. If clomazone was applied at seedling emergence, bioactivity decreased by 60%. If jointed goatgrass or downy brome was greater than 3 cm deep in the soil, clomazone was ineffective in controlling either species.

Field studies.Phorate did not affect wheat growth or grain yields when applied alone. Clomazone reduced grain yields only when applied postemergence at 0.56 kg/ha to both varieties. Both varieties showed chlorosis in early spring, but this injury did not translate into yield reduction. Clomazone at 0.56 kg/ha rate reduced tillers/ha, thus reducing final grain yield.

INTERPRETATION: Clomazone is effective in controlling downy brome in winter wheat if applied preplant or preemergence at 0.14 or 0.28 kg/ha. In some years, semi-dwarf varieties have been injured by clomazone, resulting in grain yield loss. Applying phorate does not increase winter wheat tolerance to clomazone in Colorado, but it has been effective in Wyoming. In Wyoming, phorate was applied 2-3 cm away from the wheat seed, thus preventing crop injury while still safening wheat to clomazone. In Colorado, phorate was applied in the seed-row with wheat, thus crop injury due to phorate may have minimized the safening effect. With standard height varieties, phorate may not be needed, as these varieties appear to be more tolerant to clomazone. The greenhouse data on time of application in relation to stage of growth suggests that clomazone application should occur before the first precipitation event. These results also suggests possible cultural practices (such as maintaining a no-till system to keep weed seed on the soil surface, and to plant a more tolerant variety at a specified depth to reduce the wheat's exposure to clomazone) that the producer can used to enhance the potential for successful control of jointed goatgrass or downy brome with clomazone.

FUTURE PLANS: The field study is complete, and the data has been shared with Steve Miller at Wyoming, who will be writing a manuscript based on both states' data. The greenhouse study will be completed this winter. A new study is examining the efficacy of combining clomazone with metribuzin for control of jointed goatgrass (cooperation among C. Ross, P. Westra, S. Miller, and R. Anderson in Colorado and Wyoming). Another study is testing several varieties for their tolerance to clomazone. A symposium sponsored by FMC and Pueblo Chemical Company was held in Denver in 1992, and the final consensus of participants was to continue pursuing this control technique. Pueblo Chemical Company plans on marketing this methodology.

CULTURAL MANAGEMENT SYSTEMS FOR WINTER ANNUAL GRASS CONTROL IN WINTER WHEAT

R.L. Anderson
Central Plains Resource Management Research Unit

CRIS: 5407-12130-003-00-D

PROBLEM: Herbicides options for within-crop control of downy brome are presently limited and expensive. Within-crop control measures for jointed goatgrass and volunteer rye do not presently exist. However, several cultural practices have been shown to limit the growth and interference of downy brome in winter wheat. For example, delaying planting of winter wheat allows more time for downy brome to germinate before wheat planting and be controlled by tillage and/or herbicides. Winter wheat cultivars also differ in their competitiveness with downy brome, with taller varieties tolerating downy brome interference with less yield loss. Other cultural practices reducing brome interference include narrow row spacing, increased seeding rate, and N fertilizer manipulation. Banding N fertilizer with winter wheat seed reduced downy brome density 29% and biomass 50% while increasing winter wheat grain yield 32% compared with a broadcast application at planting.

The majority of research exploring cultural practice effect on downy brome has focused on only 1 or 2 practices. The objectives of this research are to 1) compare production systems composed of various combinations of cultural practices for managing downy brome within winter wheat, and 2) compare growth of downy brome, volunteer rye, and jointed goatgrass among management systems.

APPROACH: Experimental design is a randomized complete block with four replications. Treatments consists of nine management systems composed of various combinations of cultural practices easily implemented by producers. The management systems are listed in Table 1. Plot size is 30 by 30 feet. Within each plot, the following subplots will be established: 3 weed sites (25, 75, and 150 plants/m^{-2}) where downy brome is planted, a weed-free site, an emergence site (for systems 5 and 9), and a development site where downy brome, jointed goatgrass, and winter rye will be established in pellets. Subplot size is 2 m by 3 m.

System 9 is the conventional operations currently used by producers in this region: planting a semi-dwarf cultivar in mid September with 30 cm row spacing at 45 kg/ha. Nitrogen fertilizer (67 kg/ha) was applied in August with a tillage operation (for weed control).

Downy brome emergence between August 1 and November 15 was recorded from 1 designated m^2 sites in each plot for system 5 and 9. Downy brome is also being counted within the winter wheat canopy for all plots 6 weeks after planting for all systems. Before June 15, downy brome and winter wheat composition of the community biomass will be determined from 1 m^2 per plot. Seed production of the downy brome will be determined from these sites.

Winter wheat yield will be determined from the weed-infested and weed-free sites by harvesting 60 ft^2 with a small-plot combine. Yield components of winter wheat will be determined for both weed-infested and weed-free sites. Tillers per designated m^2 will be recorded, 20 spikes randomly selected from this m^2 site, and number of seeds/culm and seed weight will be determined.

Downy brome, jointed goatgrass, and winter rye development is being monitored from 6 plants established with pellets for each system in all replications. The pellets will be established at planting and in the spring for all systems.

Table 1. Management systems composed of various combinations of cultural practices.

System	N application	Variety	Seeding rate
1.	Band	Tam 107	45 kg/ha
2.	Band	Lamar	45
3.	Band	Tam 107	73
4.	Band	Lamar	73
5.	Broadcast	Tam 107	45
6.	Broadcast	Lamar	45
7.	Broadcast	Tam 107	73
8.	Broadcast	Lamar	73

9. Control treatment for comparison: broadcast 67 kg N/ha, Tam 107, 45 kg/ha seeding rate. Standard practices used by producers.

N Band application: N was banded with the seed at planting at 18 kg/ha. The remainder of N was broadcast in April. The broadcast N treatment was applied in April. Final N application was 67 kg/ha.

FINDINGS: The study has been established and the initial growth staging is being recorded.

INTERPRETATION: None at this time.

FUTURE PLANS: The results from this study will be used to develop a study exploring management systems for control of jointed goatgrass, downy brome, and volunteer rye. The systems will be longer-term in time, involving rotations, mowing, cultural practices at planting time, and control options within the crop.

WEED MANAGEMENT SYSTEMS FOR SUNFLOWER

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PROBLEM: Sunflower has potential to become a major crop in the Central Great Plains. It is classified as a non-compliance crop in the government program, thus, producers can grow sunflower without affecting their wheat base. However, one obstacle to sunflower production is residue level compliance for the government program. The prevalent herbicide used for weed control in sunflower is treflan (trifluralin), which requires incorporation for effective control. This incorporation eliminates surface residue and results in fields failing to meet the 30% cover requirement after planting.

A granular formulation of treflan applied at 1.1 kg ai/ha with limited incorporation has been successful in North Dakota. Application occurs in late fall or early spring, and a sweep plow (1 or 2 operations) is used for incorporation. This technique minimizes residue burial and relies on precipitation to aid in incorporating the granules.

Prowl (pendimethalin) has performed well when surface-applied without incorporation. Applying prowl at 1.5 lb/ac in mid-May controlled weeds for 90 days during chemical fallow, while a 1.0 lb/ac rate controlled weeds in safflower for 63 days. Prowl is currently labeled for preplant-incorporated use in sunflower.

Tillage intensity affects crop growth in the Central Great Plains. For example, grain yields of corn, proso millet, and safflower were increased by 35, 20, and 10%, respectively, in a no-till system when compared to a tillage system of sweep plowing and disking for weed control and seedbed preparation. Tillage effect on sunflower production, however, has been inconsistent. In eastern North Dakota and Texas, sunflower grain yields were not affected by tillage system, while in central North Dakota, no-till systems increased grain yields only during drought years, not during normal precipitation years.

The objective of this study is to compare management systems composed of combinations of tillage and herbicides for controlling weeds in sunflower.

APPROACH: Six systems will be compared, 4 with a stubble mulch fallow and 2 with no-till fallow. The stubble mulch fallow consists of sweep plowing as needed in the fall and spring before sunflower planting. The 4 treatments in stubble mulch fallow are: 1) liquid treflan (1.0) applied in May and incorporated with a disk; 2) granular treflan (1.0) applied in October, followed by a second application of granular treflan (0.5) in May; 3) granular treflan (1.0) applied in May; and 4) granular Sonalan (1.0) applied in May. No-till fallow consists of command + atrazine (0.5 +0.5) applied in late July. The 2 treatments in no-till fallow are 5) granular treflan (1.0) applied in May and 6) liquid prowl (1.50) applied without incorporation. Treflan in treatments 2, 3, and 5 and Sonalan in

treatment 4 will be applied with the Gandy air system and incorporated with the sweep plow and mulch treaders. Nitrogen will be applied at 60 lbs/acre for stubble mulch fallow treatments and 80 lbs/acre for no-till fallow treatment.

Experimental design will be a randomized complete block with 4 replications. Plot size will be 30 by 40 feet.

Data goals are:
1) Water storage and use. Soil water storage and water-use-efficiency will be measured by gravimetric samples (1-foot increments to a 6-foot depth) taken after wheat harvest, November 1, April 1, before sunflower planting, and after harvest.

2) Winter wheat residue measurements. Using the line transect method, residue levels will be measured after wheat harvest, November 1, April 1, at sunflower planting, and after sunflower harvest.

3) Sunflower growth and grain yields. Sunflower development and plant height will be recorded weekly on 3 designated plants per plot. Sunflower biomass will be measured at flowering from two 1-m^{-2} quadrats, with grain yield and 1000-seed weight recorded at harvest. Biomass samples will be collected and ground through 100-mesh screen at flowering (all biomass in one sample) and at maturity (seed, stalks, and heads in separate samples). These samples will be analyzed for N, K, P, and organic carbon concentration.

4) Weed control. Visual estimates of % of plot area that is weed-free will be made weekly until canopy closure. When level of weed infestation exceeds 15% of the plot area, weed biomass by species will be recorded from two 1-m^2 quadrats in each plot. If weed cover does not exceed 15%, species, population, and biomass will be recorded at canopy closure. Four m^2 sites will be marked in a no-till site and stubble mulch site within appropriate treatments in the study and weekly emergence of weed species will be recorded during the sunflower growing season (June 10 - Nov. 1).

5) Economic cost of systems. Tillage operations for each plot, herbicide inputs and costs, and grain yield will be used to calculate the economic return per investment for each system.

FINDINGS: The study was established and initial soil water and residue levels were measured.

INTERPRETATION: This study will supply data for producers in choosing conservation tillage systems to grow sunflowers within government compliance regulations. The study is also designed to evaluate the effect of tillage intensity on sunflower seed production. The results will be immediately applicable for guiding producer decisions.

FUTURE PLANS: Conclusions from this study will be used to guide future research, in no-till sunflower production systems.

GROWTH AND INTERFERENCE OF PROSO MILLET IN DRYLAND CORN

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PROBLEM: Producers in the western part of the Central Great Plains are changing their crop rotations from winter wheat-fallow to more intensive cropping, where several crops are planted sequentially before a fallow period occurs. As producers move towards more flexibility in cropping options, one potential crop sequence would be planting dryland corn after proso millet. Wild proso millet is a prevalent weed in the northern cornbelt. Producers use intensive herbicide inputs at a high economic cost to prevent significant yield losses due to wild proso millet interference. At present, the most successful control measures for wild proso millet have included preplant-incorporated herbicides plus postemergence directed-spray herbicides which require a substantial height differential between the millet and corn to avoid corn injury. Knowledge of the developmental patterns of volunteer proso millet within a corn canopy would guide effective use of postemergence-directed herbicides.

The objectives of this study are: 1) evaluate the emergence patterns and development of proso millet within a corn canopy in a no-till and tilled production system; 2) evaluate herbicides for the control of proso millet in corn.

APPROACH: Proso millet emergence was determined for no-till and till treatments. The till treatment was disked twice two weeks before planting corn. Four m^2 sites per each tillage treatment were designated at planting, with proso millet emergence from the soil seed bank recorded weekly and the plants removed after counting. Soil temperature was measured hourly at the 1.3 cm depth with a data logger. Twelve proso millet seedlings (germinated in the greenhouse in peat pellets) were transplanted in the field in six replications every two weeks from corn planting until August 1. Development stage and plant height were recorded weekly. At maturity, the plants were harvested for biomass and seed production. Plot area was maintained weed-free by hand weeding.

Corn was planted on April 29, May 6, May 13, May 20, and May 29, at 25,200 plants/hectare. Experimental design was a randomized complete block with four replications. Plant height and development were recorded weekly on two designated plants per plot. Grain yields were recorded at harvest.

Four herbicide treatments were evaluated for control of proso millet in corn: 1) eradicane (EPTC) at 4.5 kg/ha + row cultivation (if needed) in late June; 2) command (clomazone) at 0.8 kg/ha applied preemergence; 3) command at 0.8 kg/ha applied preemergence with bladex (cyanazine) + prowl (pendamethalin) at 1.7 kg/ha + 1.1 kg/ha applied early postemergence (when proso millet was just emerging); 4) command at 0.8 kg/ha + paraquat at 0.3 kg/ha applied post-directed when corn was 40 cm in height. Atrazine at 1.1 kg/ha was applied to all treatments in late April to eliminate all other weeds. Weed-free and weed-infested controls were included for comparison. Corn was planted at 36,570 plants/ha. The experimental

design was a randomized complete block design with 4 replications. Biomass measurements were taken on July 31 (at silking), and grain yields were recorded at harvest.

FINDINGS: Proso millet emergence was later than the previous years because of lack of precipitation in April and May. Emergence peaked in early June, with > 90% occurring within a 2-week period. The total number of seedlings were 282 plants/m^2, approximately 2.5 times the emergence of the previous year. Proso millet growth within the corn canopy was affected by time of emergence. The dry matter production of proso millet that emerged on June 1, June 15, July 1, July 15, and August 1 was 30.8, 4.4, 1.5, 0.2, and 0.1 grams/plant, respectively. A plant emerging on June 1 produced 2185 seeds, while a plant emerging 2 weeks later produced only 360 seeds. The ecological data on proso millet emergence and productivity indicates that the critical control period is between May 15 and June 21.

Corn yield was affected by time of planting. Grain yields were 4700, 5360, 4810, 3960, and 3820 kg/ha for the April 29, May 6, May 13, May 20, and May 29 planting dates, respectively. Coupled with the height differential data, the grain yield data suggests that corn planted before May 10 allows for maximum flexibility in proso millet control while producing high grain yields.

Eradicane, command + paraquat (post-directed), and command + bladex + prowl provided excellent control of proso millet (> 90% control at harvest). Command alone controlled proso millet early in the growing season, but long-term control with command will require a second weed control operation, such as row cultivation or a post herbicide application.

Corn yields were highest with the no-till treatments of command + bladex + prowl and command + paraquat. The eradicane treatment yielded only 58% of the command + paraquat treatment, even though weed control levels were similar. This yield loss is attributed to the lack of residue on the soil surface (due to disking for incorporating eradicane in early May) increasing soil water evaporation. This tillage effect also occurred in 1991.

INTERPRETATION: The ecological data indicates that the critical period for proso millet to affect corn is between May 15 and June 15. Post-directed applications of paraquat are effective in controlling proso millet in corn. Control of proso millet in dryland corn is achievable, but economic costs will be high.

FUTURE PLANS: Management systems suggested by the ecological data will be examined in the future, within economic limits currently facing the producers.

PSEUDOMONAS BACTERIA AS A BIOLOGICAL CONTROL AGENT FOR DOWNY BROME IN WINTER WHEAT

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PROBLEM: In the United States, downy brome (Bromus tectorum L.) and related Bromus species infest an estimated 5.7 millon hectares of dryland winter wheat. At the current market value for wheat and using available herbicides, downy brome is still reducing wheat yields by an estimated 15% or 300 million dollars. In addition, these herbicides cost farmers 35 to 70 million dollars annually depending on herbicide choice and usage. Other costs include reduced harvest efficiency, increased dockage, future weed control costs, and adoption of less economic cropping systems. Also, as tillage is reduced to adopt conservation practices, the incidence of downy brome increases as does the use of chemical to control this weed.

Increased awareness of the environmental risks associated with the excessive use of chemicals to control weeds in agricultural production has stimulated investigation into the use of microorganisms as alternative control methods. Biological control can potentially reduce the dependence on chemicals and increase the cost effectiveness of pest control. Biological control using plant pathogens, usually fungi, has been effective in the control of certain weeds. Recent studies have shown the ability of deleterious rhizobacteria (Pseudomonas spp.) to suppress the growth of downy brome without injuring winter wheat.

The objective of this study is to evaluate the performance of a selected strain of Pseudomonas rhizobacteria for bioactivity on downy brome over several locations in the Western U.S. (Akron CO, Hays KS, Pullman WA, Pendleton OR, and Moscow ID).

APPROACH: Field plots were established on an Ascalon sandy loam soil. Eight treatments were evaluated: 1) nontreated control; 2) rhizobacteria strain D7 at 10^9 bacteria/m^2; 3) diclofop at 1 kg/ha; 4) diclofop at 0.5 kg/ha; 5) rhizobacteria strain D7 at 10^9 bacteria/m^2 + diclofop at 0.5 kg/ha; 6) metribuzin at 0.3 kg/ha; 7) metribuzin at 0.15 kg/ha; and 8) rhizobacteria strain D7 at 10^9 bacteria/m^2 + metribuzin at 0.15 kg/ha. Experimental design was a randomized complete block with 4 replications. Plot size was 4 m by 8 m.

Soil and plant (winter wheat and downy brome) samples were collected 0, 7, 21 days after rhizobacteria application, plus in November, February, April, and June. Samples were sent to Pullman for rhizobacteria population measurements. Seed production and biomass of downy brome at physiological maturity of the weed were determined in mid to late June from 2 1-m^2 sites. At winter wheat maturity, grain and biomass yield, and yield components of winter wheat were recorded.

FINDINGS: Bacteria was not detected in any soil or plant sample collected during the growing season at any of the sites. This lack of success in bacteria colonizing wheat roots occurred at all sites (Colorado, Kansas, Washington, Idaho, and Oregon). The scientists at Pullman are re-directing their efforts to develop a formulation in which the bacteria can be applied with the wheat seed at planting.

Downy brome did not emerged at Akron until March. Treatments affected population levels in the spring: diclofop and metribuzin at normal use rates reduced downy brome populations by 93 and 100%, respectively. Downy brome emerging in the spring produced > 2000 seeds/m^2 in the control. Not only did diclofop reduced plant density by 93%, but it reduced seed production by 83%. Yet, downy brome still produced 400 seeds/m^2 in the diclofop treatment. This data shows that spring-emerging downy brome can add significantly to the weed seed bank in soil.

Winter wheat grain yield was not affected by treatment or downy brome population. Yields averaged 2450 kg/ha. The lack of downy brome effect on grain yields agrees with previous research, where yield loss occurs only if downy brome emerges within 3-4 weeks of winter wheat emergence.

INTERPRETATION: This study showed that the rhizobacteria will not survive and infest plant roots if applied to the soil surface. The USDA-ARS unit at Pullman is exploring formulations that will enable the bacteria to be banded with wheat seed in the row, therefore establishing on wheat roots. If downy brome roots contact wheat roots in the soil, the bacteria will transfer to downy brome. Because the bacteria does not move in the soil, this formulation will affect only downy brome growing in the row. Other technologies will be required for between-row control of downy brome (such as Command applied preplant to wheat).

FUTURE PLANS: The incumbent has been invited to establish a site testing the efficacy of new formulations which can be applied in the row. The target date for this new study is September, 1993.

TOLERANCE OF OATS, FOXTAIL MILLET, PROSO MILLET, AND SUNFLOWER TO CLOMAZONE (COMMAND) AND ATRAZINE

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PROBLEM: With the development of more efficient methods for weed control during non-crop periods in the Central Great Plains, producers are cropping more intensively. Spring-planted crops such as corn, proso millet, and safflower have been successful in a winter wheat - spring-planted crop - fallow rotation. This two-crop-in-three-year rotation uses precipitation more efficiently in grain production, and also aids the producer from a pest management perspective.

Atrazine is the prevalent herbicide used for weed control in no-till fallow methods. Clomazone is also currently registered for use during fallow. Clomazone controls jointed goatgrass (Aegilops cylindrica Host) and downy brome (Bromus tectorum L.), weeds which atrazine is ineffective in controlling. Safflower, corn, and proso millet are tolerant of fall applications of clomazone, but producers are seeking other alternative crops to grow after winter wheat. Knowledge of crop options during a chemical fallow system would increase the flexibility producers have in selecting crop rotations. The objectives of this study are: 1) evaluate the biological response of oats, foxtail millet, proso millet, and sunflower to fall applications of clomazone and atrazine, 2) determine the duration of residual weed control by clomazone and atrazine within the crop canopies, and 3) compare the water use among these crops.

APPROACH: Clomazone and atrazine were applied on August 15, 1990, at 0, 0.5, and 1.1 kg/ha, alone and in all possible combinations, resulting in 9 treatments. The site was maintained as a no-till system. Oats, proso millet, foxtail millet, and sunflower were planted perpendicular to the herbicide treatments in the spring of 1991. The experimental design was a split block design with the crops planted in strips across the herbicide treatments which were arranged in a randomized complete block. There were four replications. Oats were planted in early April, and the millets and sunflower were planted in the first week of June. Planting rate for each crop was 70 kg/ha for oats, 12 kg/ha for both millets, and 50,000 plants/ha for sunflower. Ammonium nitrate was applied at 56 kg N/ha for oats and sunflower, and 36 kg N/ha for the millets. Herbicide injury to crops was assessed 3 and 6 weeks after planting by visual evaluations and biomass measurements. Residual in-crop weed control was assessed weekly. Forage yields were determined for oats and foxtail millet at the early milk and heading stage, respectively. Grain yields and biomass production of proso millet and sunflower were determined at maturity. Water use was measured gravimetrically before planting and after harvest for all crops.

FINDINGS: Crop response to herbicides. The data summarized in this report are from the Akron site only. Visual symptoms were not observed with any crop in this year (clomazone causes a white bleaching of the leaves and atrazine causes a bronzing of the leaves with tip burning), nor did the herbicides affect

productivity of any crop. Oats biomass production averaged 4100 kg/ha, while foxtail millet produced 3600 kg/ha of forage. Grain yields of proso millet and sunflower averaged 2700 kg/ha and 1900 kg/ha, respectively. Total water use was 265, 237, 328,and 464 mm for oats, foxtail millet, proso millet, and sunflower, respectively.

Weed control duration. All herbicide treatments controlled weeds during fallow until early June. At that time, only treatments with clomazone at 1.1 kg/ha plus various rates of atrazine were weed-free. All other plots (except for the oats plots) were sprayed with paraquat before planting of foxtail millet, proso millet, and sunflower. Clomazone plus atrazine (1.1 + 1.1 kg/ha) maintained acceptable weed control in sunflower until canopy closure on August 1. The duration of weed control by clomazone and atrazine combinations was similar to previous research conducted at the Akron station. No further within-crop weed control was applied for oats, foxtail millet, or proso millet, yet all crops were relatively weed-free at harvest. Precipitation was low after planting, thus allowing the crop canopies to develop before weeds emerged.

INTERPRETATION: Producers applying clomazone + atrazine combinations for fallow weed control have flexibility in crop choice the following spring. In conjunction with previous research conducted at this station, this study demonstrates that safflower, oats for forage, corn, foxtail millet, proso millet, and sunflower can be grown after a clomazone-atrazine application (at 0.6 + 0.6 kg/ha) the previous fall, without suffering crop injury. The advantage of combining clomazone and atrazine is increased control of jointed goatgrass and downy brome as compared to atrazine applied alone. This flexibility in crop choices enables the producer to maximize water use by crops while still controlling weeds during fallow and maintaining adequate residue levels on the soil surface for erosion control.

FUTURE PLANS: The data is being analyzed and will be submitted for publication in Weed Technology. This team is now exploring weed management systems for reduced-till and no-till sunflower production.

METHOD DEVELOPMENT FOR EVALUATION OF C AND P POOLS TO ASSESS SOIL QUALITY

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PROBLEM: In the semiarid areas of the Great Plains, continued wheat-fallow cultivation of the native grasslands has resulted in significant losses of soil organic matter (SOM) because of decomposition. This loss is even greater because of the high erosion hazard associated with plowing the plains areas where winter winds are pronounced during the fallow periods. This loss of SOM results in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical and chemical properties such as rooting depth and soil aggregation. Total pools of organic C and P in croplands are sometimes inadequate as predictors of trends in soil deterioration because they lack sensitivity over the short term (1 to 3 years). A need exists to develop methodology to assess soil quality changes and direction of change. The specific objective, therefore, was to develop sensitive organic C and P methods to assess soil quality, and consequently, soil productivity in croplands. Methodology will be based on correlations with measures of soil microbial activity such as the phosphatase activity, and on water- and base -soluble organic C and P, and carbohydrate-C (binding for aggregates) which, hopefully, may integrate losses due to erosion, decomposition, and gains due to organic matter inputs from previous cropping.

APPROACH: Soils from 22 alternate cropping plots and two adjacent native sod sites were used to test extractability of organic C and P from water (high soil/solution ratios) and dilute base solvents (NaOH with and without EDTA). These soils were selected so true comparisons could be made between no-till and reduced-till treatments. In other words, only the same cropping sequences were compared. As before, these pools were regressed against total pools, established methods for labile pools, and selected measures of soil microbial activity such as the phosphatase activity for biological correspondence. Where possible organic C and P were measured in the extracts, and color intensity of basic extracts was determined as a measure of total C along with established methods for total organic P. A procedure to evaluate structural or aggregate stability (used by the salinity group at Riverside) was initiated in which the flocculation-dispersion behavior of the clay was measured by optical transmittance (turbidity). The aggregated clays are more flocculated, and therefore show a greater light transmittance when allowed to settle overnight. A method for soil carbohydrate is also being tested.

FINDINGS: Extractants for a measure of soluble C tested were: water, 0.05 M $NaHCO_3$, 0.05 M NaOH, and 0.05 M NaOH after treatment with 1 M acid. The intent was to come as close as possible to the pool in the solution phase while at the same time having a relatively easy and reproducible way of extracting sufficient measurable organic C. Thus, more dilute base solutions were used as opposed to the more concentrated ones used in the initial studies. The ideal solution /soil ratio under the shaking conditions was 2 (8 g soil to 16 mL solvent). A one-h shaking time was used to extract the carbon. As before, total C was estimated

from colorimetric procedures based on dichromate reduction and on extract color absorptivity (NaOH and NaOH plus EDTA) at 550 nm. Initial results from the turbidity study indicated clear differences between cultivated and native sod plots, the latter showing lower turbidity. The carbohydrate procedure is being modified since present method used is tedious and very time consuming.

INTERPRETATION: Sampling was increased from 6 to 24 sites to obtain a better representation of treatment effects. Results showed that organic C measured in aqueous extracts of high soil/solution ratios may reflect sensitive short-term changes. However, about 20% of the aqueous samples had colloidal material in the reduced dichromate colorimetric solution. This required an extra step of centrifugation to eliminate the precipitate. Thus, the method of choice at this time is extraction with 0.05M $NaHCO_3$ where there is no turbidity interference. Data for the residual organic C showed higher values for longer rotations sequences especially where millet was last grown (still needs much more evaluation though), and lower values under conventional till. Turbidity studies could be handled a lot more routinely if shown to be well correlated with aggregation studies and infiltration studies. Trends among cultivated sites still need to be developed since differences may be small.

FUTURE PLANS: Methodology development will continue with more tillage and rotation combinations, and with soils that provide distinct differences in organic matter such as soils in a catenary sequence, and soils in various phases of grass reestablishment (Conservation Reserve Program). Soils from the CRP will be obtained in the spring as part of another program. Emphasis will be placed on correlations of water-soluble and residual organic C with the various cropping sequences. Carbohydrate-C and turbidity studies will also continue as an indicator in evaluating aggregate stability. A Soil Quality Index (SQI) will be developed based on differences between native and adjacent cropped sites.

P, C, AND MICRONUTRIENT DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

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PROBLEM: The dominant dryland cropping system in the Central Plains is the two-year cycle of conventional-till (CT) winter wheat and fallow (WW-F). Numerous studies in the Great Plains have shown that this system may not be the best for efficient utilization of water and nutrients. Additionally, if one could introduce another crop or two into the rotation system without a deterioration in soil productivity (No-till (NT) systems) or weed infestation (Reduced-till (RT) systems), then farm income can be obtained 8 or 9 times in 12 years as opposed to 6 in a conventional wheat-fallow system. The challenge then becomes one of choosing the right set or sets of rotations, that are economically desirable and simultaneously maintain or improve soil productivity. This is the objective of the station team research. My specific objectives are: to monitor changes in soluble and total organic matter, P, and Zn under selected alternate cropping (one to four-year rotations) and tillage (NT, RT) systems as compared to the standard clean-till wheat-fallow rotation. Additional objectives are to monitor changes in pH, bulk density, texture, aggregation, and infiltration.

APPROACH: The study is located at Akron CO on a Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist (See report by Halvorson, Hinkle, Nielsen, Anderson, Bowman, and Vigil for treatments). Extensive sampling was conducted on all 180 sites for soluble and total organic carbon, color intensity of base extraction, pH, bulk density, phosphatase activity, bicarbonate-extractable P, total organic P, and total P.

FINDINGS: Soil samples were collected at 0-15 cm, and at 0-5 cm for plow layer evaluations and for stratification evaluations especially under the no-till conditions. Generally, data on organic carbon showed a definite trend towards increasing carbon content as cropping intensity increased. Wheat-fallow systems contained the least organic matter content while continuous cropping contained the most. Average loss of organic carbon in plots when compared to the native sod was about 40% The data showed that conventional cropping had the highest soluble organic carbon content. There was a significant drop in pH (0.01M $CaCl_2$) because of cultivation (pH = 5.7) when compared to the native sod (pH = 6.5). Although not significant, there was a trend towards higher bulk density for no-till treatments.

INTERPRETATION: Conventional-till treatments had the highest soluble carbon content probably because of greater mixing and exposure to oxygen, and consequently, greater degradation of larger compounds. This also causes the greater loss in total organic carbon because of decomposition to CO_2. Cropping intensity increases organic matter because of greater residue production. The drop in pH was to some extent due to the use of ammoniacal fertilizers over time.

While no-till also causes a drop in pH (organic acid production in the surface soil), pH for reduced-till was about the same. As more data are collected, and more compositing of cropped and fallow , conventional and no-till are done, changes in labile forms of OC and P will become more evident. Significant results from study may require a number of years since complete cycles range from one to four years, and 12 years are required for adequate standardization.

FUTURE PLANS: Plans are to reevaluate carbon data for inconsistencies and probable reruns, and to establish this baseline information for all 180 sites (depth 0-15 cm); and to do the same for total N. On selected site samples, we hope to evaluate CEC, aggregation, texture, and water infiltration, and to continue to determine labile pool changes of C, N, and P. At this time, there is no intention to study micronutrients unless field plant symptoms show specific needs. An attempt will be made to develop methods to separate carbon losses due to decomposition and to erosion.

P and ZN DYNAMICS IN NO-TILL WHEAT AND CORN

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CRIS: 5407-12130-003-00-D

PROBLEM: No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat because of its higher dry matter production (40 bushel dryland wheat requiring about 83 kg N and about 12 kg P, with 75 bushel dryland corn requiring about 100 kg N and 18 kg P / ha). The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies.The objectives of the research, therefore, are to evaluate the need for P and micronutrients in no-till wheat and corn, to measure changes in forms and availabilities of P with time, and to predict yield responses for these nutrients.

APPROACH: Two sites have been selected, one at Peetz, CO for evaluation of no-till wheat (See report of Halvorson and Havlin for plot design and treatments), and one at Akron, CO on a Platner loam soil also for wheat (previously in corn). Only the broadcast sites with N (40 sites) are been studied at Peetz. Treatments for the corn study are: four replications with randomized NP factorial (4 N x 5 P for a total of 20 treatments per replication). Nitrogen applications were: 0, 40, 80, and 120 lb/Ac of N as NH_4NO_3, and 0, 30, 60, 90, and 120 lb/Ac of P as triple superphosphate (0-46-0).
For the wheat study soil samples were taken from both east and west plots in May and June, 1992, and from previous collections by Halvorson and Havlin. Whole wheat plants were harvested once only . Total and available P pools were determined on the soils, and total N, P, and Zn on the plants. For the Akron site soil samples were taken down to 90 cm on all 60 sites, and to 180 cm on the 0 and 120 P sites in October. Whole plant samples were taken in November.

FINDINGS: Data on early P uptake in wheat (both sites) showed that the increasing P treatments resulted in corresponding increases in tissue-P content. Tissue-P concentrations also increased because of N content at the Peetz site, but this was only evident with the highest N level at the Akron site. Soil available P has been determined on all soil samples for both sites. There were no P deficient plots at the Akron site with the controls (zero P) averaging 26 ug/g.

INTERPRETATION: In both wheat studies, soil levels of available P were high, average for 0 P in the wheat at Peetz being about 15, and that at Akron about 28. There may have been a problem with the application of the P fertilizer at the Akron site since this is the second year in a row that values have been above 20 where previous values before study were 10. Method of P application (broadcast, incorporated) did not seem to influence P concentration at this point of early

growth. Data for P sequential fractionation at the Peetz site showed that the increasing P fertilization could be recovered in labile and moderately labile inorganic P fractions. The bulk of the P is still associated with the Ca-P minerals.

FUTURE PLANS: We will continue to monitor changes in P and Zn and Fe in wheat and corn samples. Because of the high P levels at the Akron site, we may have to abandon this study or change its objectives since P response is quite unlikely even though initial uptake may be greater where P is higher. The initial soil samples (1986) will provide the basis from which changes will be evaluated for the Peetz site. Akron site was previously part of an entomological experiment with wheat to assess high P effects on Russian wheat aphid infestation. Future changes will be assessed relative to the 1992 sampling.

COMPARISON OF CRP LAND IN VARIOUS STAGES OF REST WITH WHEAT-FALLOW AND ADJACENT GRASSLAND

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CRIS: 5407-12130-002-00D

PROBLEM: Present Center projects relevant to CRP address soil and vegetation changes on small station plots (See Halvorson and see Schuman). Hopefully, with other things being equal, these small plots will reflect the changes occurring in the over 30 million acres of highly erodible cropland set aside in grass for at least 10 years as part of the Food Security Act of 1985. A principal question in this billion-dollar experiment is whether the rested cropland will be able to adequately support cropping again, and under what conditions or restraints this should be done. Obviously, if soil conditions are deemed inappropriate, a site could remain in grass. A main objective of this research, then, is to develop a set of criteria based on soil physical, chemical, and biological properties to determine adequacy for release of CRP lands back to cropping. An opportunity exists in Washington County to extend this field laboratory research to actual on-farm analysis of farmers' fields that have been in CRP for various lengths of time, the longest requiring three more years to complete its 10-year cycle. Data collected will reflect the true state of affairs and magnitude of change for these once fragile lands.

APPROACH: Nine farms in Washington County on the Conservation Reserve Program were selected from data obtained through SCS. Three went into the program in 1986, three in 1988, and three in 1990. These farms were selected because they also had conventional wheat-fallow and native grassland sites nearby. Thus, one can simultaneously evaluate and compare changes under all three conditions: the original system (grassland or rangeland), the traditional farming system (winter wheat-fallow), and the CRP.
Soil parameters of interest include: organic carbon, TKN, available P, Cation Exchange Capacity, pH, texture, bulk density, water infiltration, and aggregation. Soils will be sampled at 0-15 and 15-30 cm with a minimum of three field replications with five composites. Forage quality among the three CRP sites will also be evaluated.

FINDINGS: Sampling will start in late spring, 1993.

INTERPRETATION: None yet.

FUTURE PLANS: Spring sampling, and initiation of analyses shortly thereafter.

MANAGEMENT OF PHOSPHORUS FERTILIZER FOR DRYLAND WINTER WHEAT IN REDUCED TILLAGE SYSTEMS

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CRIS: 5407-12130-003-00-D

PROBLEM: Information on management of phosphorus (P) fertilizer in no-till and reduced tillage systems for winter wheat production in the Central Great Plains is limited. Banding of low rates of P near the seed on soils low in available P has been shown to be more effective than broadcast applications of P at the same rate during the first year of application. As the soil test P level increases from low to high, the yield difference between banding and broadcast applications is expected to decrease. On a long-term basis, a broadcast application of P may be equally as effective as a band application at equal rates for wheat production. Application of a one-time, high rate of P fertilizer may be one way to satisfy the P needs of crops grown with reduced tillage and no till systems for several years. This study evaluates this suggestion along with comparing the effects of P placement method on the long-term effectiveness of residual P fertilizer within reduced tillage systems. Objectives of this study are to determine: 1) the most efficient P fertilizer placement method for winter wheat production in reduced tillage systems; 2) the level of P fertilizer needed for optimum winter wheat yields with and without N fertilization; 3) residual P fertilizer effects on winter wheat grain yields in reduced tillage systems; and 4) the effects of N and P fertilization on water-use efficiency by dryland winter wheat.

APPROACH: A split-split plot, randomized block design was used with P placement method as main plots, P fertilizer rate as subplots, and N fertilizer rate as sub-subplots with four replications. The research is located about 6.2 km west of Peetz, Colorado. Specific treatments are as follows:

1) Phosphorus Fertilizer Placement Methods
    a) Broadcast with no incorporation (BCNI)
    b) Broadcast with a shallow disk incorporation (BCI) (15 cm depth)
    c) Deep Band at about a 10 cm soil depth (DB)
    d) Band directly with seed (SP) at 25% of established P rates for 4 crop years
2) Phosphorus Fertilizer Rates Applied in September 1985: 0, 34, 67, 101, and 134 kg P/ha. Reapplied to deep band treatments by mistake in Sept. 1989 for total P rate of 0, 60, 120, 180, and 240 lb P/a for this treatment only.
3) Nitrogen Fertilizer Rates: 0 and 56 kg N/ha

Grain yield, N and P uptake by grain, soil P, soil NO_3-N, and soil water were measured.

FINDINGS: Winter wheat yields at the Peetz site were limited by drought from April through late May, frost damage in late May, and severe hail damage after heading on May 22nd and June 14-15. Treatment differences were very limited and erratic for 1992 because of the hail. During the 1992 growing season, 27.4 cm of growing season precipitation were received from April 1st until soil sampling after harvest (August 5th), with most of the precipitation received after May 23rd. Soil water measurements indicated soil water-use of 2.7 cm from the 0 to 180 cm soil depth at harvest. This resulted in an estimated total water use by the wheat crop in 1992 of about 30.1 cm.

Grain yields were not significantly (0.05 probability level) increased by increasing levels of residual P or P fertilization. Grain yields were increased by N fertilization in 1992, but only by 53 kg/ha. Lack of response to P and N fertilization was due to hail damage. Grain yields for the fertilizer P treatments were 888, 952, 999, 990, and 985 kg/ha for the 0, 34, 67, 101, and 134 kg P/ha treatments, respectively, when averaged over N rates.

Phosphorus fertilization resulted in a significant increase in the number of heads per unit area at harvest, however, most of the heads were damaged or bent over from hail. Head counts for the residual 0, 34, 67, 101, and 134 kg P/ha treatments were 4.59, 4.91, 5.01, 5.19, and 5.31 million heads/ha, respectively. Nitrogen fertilization had no significant effect on the number of heads/ha. Grain test weights were low at this site in 1992 due hail damage and a lot of rain after crop maturity and before the wheat could be harvested, however, grain test weights increased with increasing levels of available P. Straw yields at harvest and total biomass yield at heading increased significantly with increasing P level. The total biomass yields at heading (June 19, 1992) indicate that yield potentials had been much greater than the 963 kg/ha harvested, however, the hail and frost had a devastating effect on final yield. Therefore, the data for 1992 is not very meaningful or useful for evaluating P treatment effects.

INTERPRETATION: The response of winter wheat to residual P treatments was nullified by climatic conditions during the growing season in 1992. Drought during the early growth stage and frost and severe hail at heading and grain fill severely limited grain yields. Therefore no additional conclusions can be formulated based on 1992 data. The positive effect of residual fertilizer P on winter wheat yields during the first three crop years was demonstrated. However, it will be very important to continue this study as long as possible to evaluate the long-term residual P effects on grain yield and economic returns.

FUTURE PLANS: The study will be continued in 1993 as planned. Plans are to continue summarization of the data from the Morrill site and preparation of a manuscript for journal publication.

EFFECT OF NITROGEN FERTILIZATION ON WATER-USE EFFICIENCY BY CROPS GROWN IN AN ANNUAL CROPPING SYSTEM

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CRIS: 5407-12130-003-00-D

PROBLEM: Limited water for dryland crop production in the Central Great Plains area requires that precipitation be used efficiently. Limited information is available in the Central Great Plains describing the effects of nitrogen (N) fertilization on grain/forage yield and quality, and on water-use efficiency of crops (corn, barley, winter wheat, oats) produced in a reduced tillage annual crop rotation. Basic data on soil fertility and yield-plant water relationships for these crops is needed for the Central Great Plains in order to make crop management decisions that will most efficiently use limited water supplies and fertilizer inputs.

APPROACH: A dryland study site was established on a silt loam soil located on the Central Great Plains Research Station in September 1983. The N fertilizer treatments were initially established in the fall of 1983. The phosphorus (P) soil test level was 26 mg/kg (ppm). Fertilizer N rates are 0, 22, 45, 67, 90, and 134 kg N/ha with 4 replications in a randomized complete block design. The cropping history and grain/forage yield of these treatments are given in Table 1. Because spring barley has not yielded consistently and was severely damaged by heat stress in 1990, an oat-pea forage was selected as the spring crop following corn for 1992. The plots were planted to oats (Russell, 45 kg/ha) and Tinga flat pea (34 kg/ha) on March 27, 1992 with a Haybuster model 1000 disk drill (7" spacing) and harvested for forage on June 24, 1992 with a jari mower. Ammonium nitrate was broadcast applied on March 26, 1992, prior to seeding at rates of 0, 22, 45, 67, 90, and 134 kg N/ha. Soil water, nitrate-N (NO_3-N), and growing season precipitation were monitored. Forage yield and quality were determined.

Table 1. Cropping history and grain/forage yields.

		N Rate (kg/ha)					
Year	Crop	0	22	45	67	90	134
		Yield, kg/ha					
1984	Barley (grain)	2573	3778	3729	4153	4066	3516
1985	Corn (grain)	4143	4686	5991	6326	6085	6662
1986	Barley (grain)	448	1177	2066	2346	2854	3152
1987	Corn (hailed out on Aug. 4, winter wheat planted Sept. 14)						
1988	W.Wheat(grain)	2623	3022	3235	3637	3406	3182
1989	Corn (grain)	2561	3264	3333	3771	3330	4114
1990	Barley (grain)	135	442	974	1105	957	884
1991	Corn (grain)	4257	4849	5849	6416	6112	5999
1992	Oat-Pea(forage)	732	1813	3071	3627	4377	4965
Average	(9 years)	1941	2559	3139	3487	3465	3608

FINDINGS: Oat-Pea dry matter forage yields for the 0, 22, 45, 67, 90, and 134 kg N/ha treatments were 732, 1813, 3071, 3627, 4377, and 4965 kg/ha, respectively, for 1992. Precipitation was very limiting from April through May, which resulted in the Tinga peas not developing as expected. The pea forage component was insignificant. Soil-water use by oat-pea forage was influenced very little by N level in the 0- to 180-cm soil profile in 1992. Soil water use from the 0- to 180-cm soil profile was estimated to be 15.1 cm. Growing season precipitation amounted to 12.4 cm for a total estimated ET of 27.5 cm (10.8 inches) for 1992. Thus, water-use efficiency (WUE) by dryland oat-pea forage increased as N fertility level increased up to an application rate of 134 kg N/ha. WUE levels were 26.6, 65.9, 111.7, 131.9, 159.2, and 180.5 kg hay/ha/cm water for the respective N treatments. Residual soil NO_3-N levels on October 17, 1991 following corn harvest were 10, 15, 27, 76, 145, and 476 kg N/ha for the respective N treatments.

INTERPRETATION: The dryland oat-pea forage yields, following an excellent corn crop in 1991, at this annually cropped site were very acceptable in 1992. The 1992 forage yields were reduced due to very low levels of precipitation during the early growth stage (April through late May). This was the 9th consecutive crop produced on these plots since 1984. Thus, for an annual dryland cropping situation, the average grain yield (Table 1) with an adequate level of N are acceptable and economical, even with one year (1987) of total crop failure and one year (1990) of very low yield. The residual soil NO_3-N data indicate that efficient use of the fertilizer N has been made up to a rate of 67 kg N/ha. At the highest N rate, N fertilizer has been used less efficiently with a significant buildup of residual NO_3-N in the soil profile. These data demonstrate the potential to economically crop more frequently than every two years, as is done in a winter wheat-fallow system, when adequate levels of soil water and N are available.

FUTURE PLANS: The project will be continued in 1993 with each N treatment being applied at its normal rate. Corn (Pioneer 3732) will be planted no-till on the plot area in late-April 1993. Soil samples to assess the effects of N fertility rate on soil organic matter will be collected and analyzed if time permits. Plans are to complete a journal manuscript and make a detailed economic evaluation of the yield data.

CROP ROTATION AND NITROGEN FERTILIZATION FOR EFFICIENT WATER USE

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PROBLEM: In the western portion of the Central Great Plains, the winter wheat-fallow rotation is the dominant cropping system. Diversification in crop production has been limited in this area, providing producers with few economic alternatives in years when wheat is in surplus supply or soil water levels are high. The winter wheat-fallow (WW-F) system is not the most efficient cropping system for utilizing precipitation. Implementation of reduced tillage and no-till cropping systems has resulted in more efficient soil storage of precipitation. This additional water savings increases the opportunities for successfully growing spring-planted crops such as proso millet, sorghum, and corn in rotation with winter wheat. However, data on the productivity of a winter wheat-corn(or sorghum)-fallow (WW-C-F or WW-S-F) rotation is limited for the western portion of the Central Great Plains. Nitrogen management information for optimum water utilization and crop yields in these cropping systems is lacking. The objectives of this study are to measure the long-term grain yields of each respective crop in WW-C-F and WW-S-F rotations and determine the effects of N fertilization on grain yields and water-use efficiency by each crop, residual soil NO_3-N levels, and economic returns.

APPROACH: The N treatments (0, 28, 56, 84, and 112 kg N/ha applied each crop year) are randomized in a complete block design with 4 replications on a Platner loam soil near Akron, CO. Each main N plot is split following winter wheat with half the plot planted to corn and half to sorghum. Three sets of no-till plots are used to allow each crop of the rotation to be present every year. Soil water and NO_3-N are monitored to assess use by each crop. Nitrogen was broadcast to the wheat plots September 16, 1991. Wheat (Tam 107) was planted September 20, 1991 at a rate of 2.1 million seeds/ha or 850,000 seeds/acre with a Haybuster 1000 disk-type drill (7" row spacing). Corn (Pioneer 3732) was planted May 4, 1992 (36,062 seeds/ha or 14,600 seeds/a) and sorghum (Pioneer 8790) was planted May 20, 1992 (143,260 seeds/ha or 58,000 seeds/a) on the 1991 wheat plots. Ammonium nitrate was broadcast on the corn and sorghum plots on April 30, 1992. Winter wheat was harvested July 9, corn October 30, and sorghum October 19, 1992.

FINDINGS: Winter wheat grain yields were significantly increased by N fertilization in 1992. Grain yields averaged 2351, 3409, 3521, 3250, and 3128 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Extremely dry soil conditions at seeding resulted in very poor emergence of the 1992 winter wheat crop, with a major portion of the seeds germinating in February. Above normal precipitation in March 1992 helped the wheat crop survive the drought conditions from April 1st through late May, however, yield were reduced because of the water stress and a frost in late May. Grain yields increased with increasing N rate up to 56 kg N/ha and then decreased at higher N rates. Residual soil NO_3-N levels on Sept. 5, 1991 were 56, 61, 89, 70, and

142 kg N/ha (0- to 180 cm soil depth) for each respective N rate prior to N fertilization and winter wheat seeding.

Growing season precipitation (April 1 to harvest) was 15.2 cm. Average soil water use (0-180 cm depth) was 11 cm. Water use efficiency by the winter wheat, based on gravimetrically measured soil water, was improved by N fertilization with WUE of 90, 130, 134, 124, and 119 kg grain/ha/cm water for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively.

Corn grain yields were significantly increased by N application in 1992, with an average grain yield of 2430, 3791, 4709, 5602, and 5348 kg/ha at 15.5% grain moisture for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Grain yields in 1992 were greater than in 1991 due to a cool summer, and the above normal precipitation in June and August helped the corn survive the below normal precipitation conditions in May, July, and September. Yields were highest at the 84 kg/ha N rate. Silage yields (70% moisture) on August 27, 1992 were 13.7, 20.3, 25.4, 31.0, and 32.3 t/ha, respectively. Soil water use averaged 8.45 cm from the 0-180 cm profile with growing season precipitation amounting to 31.1 cm for a total estimated ET of 39.5 cm.

Sorghum grain yields were significantly increased in 1992 by increasing rates of N fertilization. Grain yields on October 19, 1992 averaged 1176, 2485, 3031, 3604, and 3906 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Average soil water use by the sorghum was estimated to be 10.3 cm from the 0-180 cm soil depth. Growing season precipitation was 31.1 cm. Estimated ET for the sorghum crop was 41.1 cm.

INTERPRETATION: Crop yields were averaged with previous years, resulting in average winter wheat yields (8 yr) of 2273, 3068, 3398, <u>3524</u>, and 3460 kg/ha; corn yields (7 yr) of 1832, 2790, 3254, 3303, and <u>3468</u> kg/ha; and sorghum yields (7 yr) of 1517, 2297, <u>2544</u>, 2531, and 2433 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments. Average corn and sorghum grain yields include the 1987 yields severely reduced by hail on August 4th (>60% loss). The winter wheat, corn, and sorghum yields at this site on this shallow soil (<120 cm to gravel) indicate the potential for more intensive crop rotations for the dryland areas of the Central Great Plains. Fertilization with N will be essential to maintain economic yields. Water use efficiency by dryland crops (winter wheat, corn, and sorghum) can be significantly increased by the application of N fertilizer. Application of 84 kg N/ha to each crop has resulted in optimum wheat yields, while 56 kg N/ha was needed for sorghum and 112 kg N/ha for corn when averaged over years.

FUTURE PLANS: The study will be continued in 1993 as planned with the same N rates and rotation of crops. Plans are to soil sample the plots to assess changes in soil chemical and physical properties. The cooperative N^{15} work with Drs. Follett and Porter will continue in 1993 with the plots possibly fallowed. Data summarization and completion of a journal publication will continue, along with initiation of an economic analysis.

NITROGEN FERTILITY NEEDS OF CROPS GROWN WITHIN A REDUCED TILLAGE, FLEXIBLE CROPPING SYSTEM

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CRIS: 5407-1230-003-00-D

PROBLEM: Nitrogen fertilizer management information for crops grown in flexible dryland cropping systems in the western Central Great Plains is limited. More intensive cropping systems generally require more fertilizer N than a crop-fallow system to obtain optimum grain yields. Use of a flexible cropping system, where soil water at planting is evaluated, will reduce the potential for an uneconomical return and make better use of limited water supplies in rainfed cropping systems. In 1993, a winter wheat-sunflower-fallow rotation will be initiated on this plot area because of the importance of this rotation as a result of the sunflower processing plant built in Goodland, KS. The study objectives are to: 1) determine the N needs of a dryland wheat-sunflower-fallow rotation using reduced tillage; 2) determine the effects of N fertilizer rate on water-use-efficiency by each crop; and 3) determine the economics of a wheat-sunflower-fallow rotation for the dryland area of the Central Great Plains.

APPROACH: Prior to 1990, the study objective was to evaluate the effects N placement method (broadcast vs band) and N rate on dryland crop yields within an annual cropping system using reduced-tillage methods where winter wheat and spring barley were grown rotation. A randomized, complete block design with factorial combinations of five N fertilizer rates (0, 34, 67, 101, and 134 kg N/ha) and two N placement methods (band and broadcast) with 4 replications were used. In 1990, the crop rotation was altered to a flexible cropping system with sunflower being grown in 1990 and proso millet in 1991 with no additional N applied to the previous N treatments in 1991. Because soil water levels were very low, the plot area was fallowed in 1992 and seeded to winter wheat (Tam 107) in September 1992 with no additional N applied. A winter wheat-sunflower-fallow rotation will be followed starting in 1993. Triplicate sets of plots will be established to have each phase of the rotation present every year.

Sunflowers were planted on an adjacent crop-fallow area maintained for comparison with the annual crop yields. The study is located on a silt loam soil at the Central Great Plains Research Station. A randomized, complete block design with five N fertilizer rates (0, 34, 67, 101, and 134 kg N/ha) with 4 replications was used. Ammonium nitrate was applied broadcast to each N plot on May 12th prior to a tillage operation to incorporate the treflan that was applied on May 11th. Sunflower (Triumph 565, oil) was planted on the fallowed plots on May 18 with a JD maximege drill at a seeding rate of 50,141 seeds/ha. The plots were hand harvested (30 sq.ft) on October 2, 1992. Grain yield, soil water, and residual soil NO_3-N were measured. Sunflowers were previously grown on these same plots in 1990. The plots were maintained in a no-till condition until application of the treflan in 1992.

FINDINGS: Sunflower yields were 1620, 2409, 2140, 2009, and 1763 kg/ha at 10% moisture for the 0, 34, 67, 101, and 134 kg N/ha treatments, respectively. Plot variability was high in 1992, therefore, the response to N fertilization was not significant. Growing season precipitation amounted to 28.7 cm. Soil water use amounted to 11.1 cm from the 180 cm profile, for an estimated total ET of 39.8 cm. Average water use efficiency (WUE) was 49.9 kg/ha/cm in 1992.

INTERPRETATION: The 1992 sunflower yields produced on this previously fallowed plot area were acceptable, but lower than expected due to a plant stand loss due to a disease that cause the plants to damp off and die as a seedling. The yields on fallow were double those produced in nearby plots where the soil water level was depleted by a previous crop in 1991.

FUTURE PLANS: The study will be continued with the planned changes mentioned above. Only the previous broadcast N plots will continue to receive additional N in the future. Recovery of the residual N from the band plots will be studied. Data collected to date will be summarized and examined for possible economic evaluation.

EFFECT OF TILLAGE SYSTEM AND CROP ROTATION ON WINTER WHEAT YIELDS

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CRIS: 5407-12130-003-00-D

PROBLEM: The winter wheat-fallow (WW-F) rotation is the accepted conventional crop management practice for most of the western portion of the Central Great Plains. Weeds are generally controlled during the fallow period before winter wheat planting with 4 to 6 tillage operations. Weed control with herbicides rather than mechanical tillage has made possible the adoption of reduced and no-till systems for winter wheat production. The reduced-till systems improve soil water storage efficiency during the fallow period, and often result in increased wheat yields. However, costs of herbicides for weed control during the fallow period can often result in lower economic returns than when mechanical tillage is used. Wheat yields in a winter wheat-corn-fallow (WW-C-F) rotation may be higher than wheat yields in a WW-F rotation, thus making reduced and no-till systems more economical. This study compares the effects of tillage system in a WW-F rotation with wheat yields produced in a no-till WW-C-F rotation. Specific objectives are to determine: 1) effects of tillage system and crop rotation on soil chemical, physical, and biological factors and productivity; 2) economics of various tillage systems for WW-F; and 3) differences in wheat yields obtained from a WW-F rotation and those produced with a WW-C-F rotation.

APPROACH: This dryland study is located on a Weld silt loam at the Central Great Plains Research Station, Akron, CO. The modifications to the existing two sets of identical plots were made on April 15, 1989. Anhydrous ammonia fertilizer, 56 kg N/ha, was applied using a Yetter rolling coulter on September 3, 1991 several weeks before planting winter wheat (Tam 107) on September 18, 1991 with a UFT disk drill (8 inch row spacing). Winter wheat was seeded at a rate of 2,124,200 seeds/ha. Corn (Pioneer 3732) was planted on the appropriate treatments on May 4, 1992 at a rate of 36,062 seeds/ha with a Buffalo no-till planter. Corn was seeded on plots that had been in wheat in 1991. Anhydrous ammonia, 84 kg N/ha, was applied on May 1st, a couple of weeks before planting. The continuous corn plots were reseeded on June 8th because of poor stand establishment with the May 4th planting. Specific treatments are as follows:

1) No till (NT) - Contact and residual herbicides for weed control
2) Bare Fallow (BF) - Sweep tillage in fall, plow in spring then sweep tillage
3) Stubble Mulch Fallow (SM) - Sweep, rod weeder (no plow or disk)
4) Reduced Tillage (RT) - Residual Herbicide after harvest, then spring till
5) Winter wheat-Corn-Fallow (WW-C-F) using a no-till system
6) Corn-Fallow-Winter Wheat (C-F-WW) using a no-till system
7) Fallow-Winter Wheat-Corn (F-WW-C) using a no-till system
8) Continuous Corn (CC) using a no-till system

Treatments 1-4 will be maintained in a WW-F rotation, with the fallow treatments described above. Primary data to be collected from the plots include: soil water - preplant and after harvest (rooting depth), soil NO_3-N in 0-180 cm,

grain and straw yield, crop residue - postharvest and preplant, grain test weight, number of tillage and herbicide operations performed and costs.

FINDINGS: The 1992 winter wheat grain yield data for the NT, RT, SM, BF, and WW-C-F plots were 2992, 2999, 2542, 2208, and 2255 kg/ha, respectively. Soil water use from the 0-180 cm profile averaged 14.3 cm. Growing season precipitation (April 1 to harvest) was 15.2 cm for a total estimated ET of 29.5 cm. Average water use efficiencies were 101, 102, 86, 75, and 76 kg grain/ha/cm for the NT, RT, SM, BF, and WW-C-F treatments, respectively. Average soil surface residue levels in September 1991 before wheat planting were 2701, 1670, 1098, 105, and 2916 kg/ha for the NT, RT, SM, BF, and WW-C-F plots, respectively. Corn preplant residue levels in April 1992 were 3772 and 4045 kg/ha for the CC and CFW treatments, respectively.
Grain yields of the corn grown on those plots that were in winter wheat in 1991 (WW-C-F rotation) averaged 3573 kg/ha (57.0 bu/a) and those that were in corn in 1991 (CC rotation) averaged 3583 kg/ha (57.1 bu/a). Weed control in the continuous corn plots was a problem again in 1992 (Kochia, Russian thistle, and tickle grass). Corn silage yields (70% moisture) were 20.0 and 21.9 t/ha for the continuous corn and C-F-WW plots, respectively. Soil water use by corn averaged 12.1 cm from the 0- to 180-cm soil depth. Growing season precipitation (May 4 to Oct 30, 1992) was 31.0 cm for a total estimated ET of 43.1 cm. Water use efficiencies by corn were 83.1 kg/ha/cm for the continuous corn rotation plots and 82.9 kg/ha/cm for the corn grown on 1991 wheat stubble in the C-F-WW rotation plots.

INTERPRETATION: The winter wheat yields reflected somewhat the same relative yield order as in the past, RT>NT>SM>WCF>BF, with the exception that the WCF yields were not the highest in 1992 as in previous years. The corn yields in 1992 were acceptable considering the cool climatic conditions and erratic precipitation patterns. Silage yields were great enough to be of economic value in integrated crop-livestock systems. Several more years of data will be needed before the new treatment effects can be evaluated.

FUTURE PLANS: The study will be continued as revised in the spring of 1989. The 1993 winter wheat crop should allow comparisons to be made between the WW-F and WW-C-F rotations. The soil organic matter, total N and total C levels determined on the detailed soil samples collected in the spring of 1989 will be examined for possible publication.

EVALUATION OF MANAGEMENT PRACTICES FOR CONVERTING CONSERVATION RESERVE PROGRAM (CRP) LAND BACK TO CROPLAND

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CRIS: 5407-12130-003-00-D

PROBLEM: In response to the Conservation Reserve Program (CRP), which was initiated as part of the 1985 Food Security Act, 30.6 million acres of highly erodible cropland has been seeded to grass. After the eighth sign-up (June 14, 1989), Colorado had 1.8 million and Kansas 2.5 million acres in CRP. At the end of 10 years, the land may be converted back to cropland or left in grass. Information is needed on: 1) how to convert CRP grassland back to cropland while maintaining wind erosion protection; 2) fertility needs; 3) tillage needed to convert grassland back to cropland; 4) use of herbicides to initially kill the existing grass and control the grass in a no-till system; 5) use of more intensive cropping systems to enhance soil erosion control; and 6) improving productivity of grassland by N fertilization or introduction of legumes/grass species to encourage farmers to keep the land in grass. Research was initiated in the spring of 1990 at the Central Great Plains Research Station with the following objectives: 1) determine if CRP land can be converted to cropland using strictly no-till practices; 2) determine what effect tillage method used in converting CRP land to cropland has on crop yield, surface crop residue, and profitability; 3) evaluate initial weed problems (1st two years) and the need for herbicides/tillage for weed control purposes; and 4) determine if grass production on CRP land can be increased by N fertilization and/or introduction of legumes.

APPROACH: The study is located on a Weld silt loam soil which was in crop approximately 15 years ago and then was planted back to grass. Average grass-legume composition before treatments application was 80.1% crested wheatgrass, 13.6% blue grama, 1.7% sand dropseed, and 4.6% alfalfa. A split-plot, randomized complete block design with 3 replications is being used with tillage treatments as main plots and N rates as subplots. The treatments include:

1) Tillage: a) No-till (NT); b) Reduced till (RT); c) Conventional Till (CT)
2) N Rates: 0, 45, 90 kg N/ha (applied at or prior to planting)
3) Crop Rotation: Winter Wheat-Corn-Fallow
4) Grass with/without introduced alfalfa (established only in 1st year)

The grass on the second set of crop plots was sprayed with glyphosate and 2,4-D on the NT plots on May 6, 1991, after the grass greened up in the spring and was actively growing. The RT plots were initially sweep plowed on April 4, 1991 and then sprayed with glyphosate and 2,4-D on May 22, 1991. The CT plots were initially tilled on April 4, 1991. The plots were either tilled or chemically fallowed or both until winter wheat planting. A 3rd set of tillage plots was established for the 1993 winter wheat crop. Alfalfa was planted in the grass-alfalfa plots on May 5, 1990 at a rate of 2.2 kg seed/ha with a JD disk drill that had a grass-legume box attachment. Poor stands of alfalfa were established. Alfalfa was replanted in fall 1991, with good establishment in March and early April 1992, however, drought conditions during April and May resulted in poor survival of the young seedlings. Winter wheat (Tam 107) was planted (2,099,500

seeds/ha, 850,000 seeds/acre) with a Haybuster 1000 series disk drill on Sept 20, 1991 with 22 kg P/ha placed with the seed and harvested on July 9, 1992. The grass and grass-alfalfa plots were harvested on May 20, 1992 by cutting 2 sq. m from the center of each plot. The grass was harvested early because the leaves were drying up due to the April through May drought. Corn (Pioneer 3732) was planted on May 4, 1992 with a Buffalo planter (14,600 seeds/a) and harvested on October 30, 1992.

FINDINGS: On September 6, 1991, the preplant winter wheat surface crop residue measurements indicated that the NT, RT, and CT plots had an average of 64, 24.7, and 17.3% cover and residue dry weights of 989, 405, and 386 kg/ha, respectively. From June 12, 1991 until September 19, 1991 there was a decrease in soil water content in the 180 cm soil profile of 1.7 cm on the 1992 wheat plots. Therefore, very little soil water had been stored during the short fallow period. Soil water content was similar for all tillage treatments at planting. Thus the 1992 winter wheat crop was mostly dependent on precipitation received. Winter wheat yields averaged 1134, 1209, and 1170 kg/ha for the CT, RT, and NT treatments, respectively, when averaged over N rates. The low yields are the result of lack of soil water to support the wheat crop during the drought period. There was no winter wheat response to N fertilization in 1992. Average yields were 1234, 1251, and 1028 kg/ha for the 0, 45, and 90 kg N/ha rates, respective-ly. Soil water use by winter wheat was 4.7, 3.5, and 5.6 cm in the 0- to 180-cm soil depth in 1992 for the CT, RT, and NT treatments, respectively. Precipitation from April 1 to July 15, 1991 was 15.2 cm (6") for an estimated total ET of 19.9, 18.7, and 20.8 cm. Low soil water for all the tillage treatments and minimal growing season precipitation contributed to the low yields in 1992. Soil NO_3-N (0-180 cm) averaged 112, 106, 92, and 24 kg N/ha for the CT, RT, NT, and grass plots on September 19, 1991. Thus 70 to 90 kg N/ha was mineralized during the fallow period.

Grass yields (oven dry) were 951, 938, and 1076 for the 0, 45, and 90 kg N/ha treatments, respectively. Alfalfa plus grass yields were 738, 723, and 810 kg/ha for each of the respective N rates.

Corn preplant surface crop residue levels for CT, RT, and NT plots were 1480, 1950, and 3180 kg/ha on May 4, 1992. The 1992 corn grain yields (1st set of plots) averaged 2157, 1775, and 3119 kg/ha for the CT, RT, and NT treatments, respectively. There was no grain yield response to N fertilization. Corn silage yields (70% moisture) were 26.4, 22.1, and 27.5 T/ha for the CT, RT, and NT treatments, respectively. These data indicate that the corn produced a good silage yield, however, sufficient soil water was not present to produce a greater grain yield. Average soil water use was 11.8 cm from the 180 cm profile. Growing season precipitation was 31 cm for an estimated total ET of 42.8 cm.

INTERPRETATION: The 1991 and 1992 yield and soil water data indicate that crop yields following grass will be very dependent on the amount of soil water storage that occurs during the previous fallow period.

FUTURE PLANS: Plans are to harvest winter wheat from the 3rd set of NT, RT, and CT plots in 1993, produce corn on the 2nd set of wheat plots, and fallow the 1st set of wheat plots. Data collection will continue as planned.

EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT-FALLOW

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PROBLEM: Economic strength, social stability, and a sustainable, environmentally acceptable agriculture throughout the Central Great Plains region depends on maximizing crop water use efficiency. Present cultural practices, using the winter wheat-fallow (WW-F) system, have resulted in extensive erosion by wind and water and a dependence on government subsidies. Saline seep development indicates inefficient water use in many areas of the Central Great Plains. Conservation tillage practices have enhanced infiltration of water into the subsoil. When this water is not used by crops, movement of soluble salts and agricultural chemicals into the ground water is accelerated or unproductive saline seep areas develop. National concerns for promoting an economically sustainable agriculture, which is environmentally sound, gives impetus to the need to develop dryland cropping systems that promote more efficient use of soil and water. Cropping systems that include spring crops in the rotation will also provide extra benefits by helping control winter annual grassy weeds, such as jointed goatgrass, downy brome, and volunteer rye. The study objectives are to: 1) evaluate crop rotations for more efficient water use and economic sustainability; 2) develop cropping systems that provide needed soil erosion control from wind and water; 3) reduce chemical inputs for weed, disease, and insect control in cropping systems through crop rotation; and 4) protect the soil resource base, environmental quality, and ground water quality with cropping systems that utilize water efficiently and reduce soil erosion.

APPROACH: The crop rotations were initiated in the spring of 1990 on a Weld silt loam soil at the Central Great Plains Research Station using a randomized, complete block design with 3 replications. Sufficient N is applied to each crop to optimize yield potential. Three tillage treatments are being compared for the winter wheat-fallow rotation: 1) complete-till (CT); 2) reduced-till (RT) and 3) no-till (NT). Because reduced- or no-till conditions are needed to efficiently store enough soil water between crops to make the more intensive rotations (other than WW-F) successful, a no-till or reduced-till system is being used with all other crop rotations. Tillage in these systems will be for the purpose of herbicide incorporation or to achieve occasional weed control. Crop rotations are shown in Table 1 with the 1992 yield results.

FINDINGS: All crops included in the study were planted as scheduled for harvest in 1992. Average 1992 grain/forage yields are shown in Table 1. Winter wheat yields were lower in 1992 than in 1991 and varied with the amount of soil water available in the rotation. Austrian Winter Pea stands were only fair in 1992 but grain yields (1567 kg/ha) were better than 1991. Soybean yields were better than 1991 due to the cool temperatures in 1992. Corn grain yields varied greatly, depending on previous crop grown in the rotation and the amount of soil water available at planting. Safflower and sunflower yields were

Table 1. Forage and grain yields for the various rotations and tillage treatments.

Rotation	Tillage	Biomass kg/ha	Grain kg/ha	Grain bu/a	Avg Yield (2 year)
MONO-CULTURE					
1) M	NT	4461	2419	43.2	39.1 bu/a
2) ALF	NT	2960	----	----	2879 kg/ha
3) G-ALF	NT	1914	----	----	2353 kg/ha
2-YEAR ROTATIONS					
4) W-F	CT	3604	1806	26.9	36.7 bu/a
W-F	RT	5107	2392	35.6	45.6 bu/a
W-F	NT	5574	2337	34.8	40.1 bu/a
5) W-M	NT	3559	1632	24.3	31.0 bu/a
M-W	NT	5175	2804	50.1	37.3 bu/a
6) W-SC	NT	1726	567	8.4	17.1 bu/a
SC-W	NT	22.8 (t/ha)	----	----	20.8 t/ha
7) W-AWP	RT	3075	1100	16.4	26.0 bu/a
AWP-W	RT	4216	1567	23.3	20.0 bu/a
8) FM-C	NT	3250	----	----	4133 kg/ha
C-FM	NT	22.9(t/ha)	3446	54.9	35.2 bu/a
9) M-SUN(FM '91)	RT	3816	2542	45.4	31.3 bu/a
SUN-M	RT	3235	805	25.7	----
10) C-SUN(FM '91)	RT	19.3 (t/ha)	1723	27.5	16.7 bu/a
SUN-C	RT	5341	1232	39.3	----
11) C-M	RT	15.8 (t/ha)	1139	18.2	26.0 bu/a
M-C	RT	3981	2085	37.2	33.0 bu/a
3-YEAR ROTATIONS					
12) W-C-F	NT	5143	2140	31.8	41.9 bu/a
C-F-W	NT	29.3 (t/ha)	5215	83.2	53.1 bu/a
W-C-F	RT	5530	2742	40.8	48.5 bu/a
C-F-W	RT	31.7 (t/ha)	4209	67.1	47.4 bu/a
13) W-C-M	NT	1225	592	8.8	22.8 bu/a
C-M-W	NT	25.2 (t/ha)	5186	82.7	58.1 bu/a
M-W-C	NT	3319	2021	36.1	33.2 bu/a
14) W-SAF-M	RT	2253	592	8.8	20.8 bu/a
SAF-M-W	RT	5374	1515	30.1	22.4 bu/a
M-W-SAF	RT	2153	1611	28.8	27.5 bu/a
15) W-M-F	RT	3470	2254	33.5	39.0 bu/a
M-F-W	RT	4475	2692	48.1	42.8 bu/a
16) W-SOY-OP	RT	1300	514	7.7	20.9 bu/a
SOY-OP-W	RT	2614	1080	17.2	13.0 bu/a
OP-W-SOY	RT	2378	----	----	2256 kg/ha
4-YEAR ROTATIONS					
17) W-C-M-F	NT	5119	2669	39.7	44.3 bu/a
C-M-F-W	NT	23.5 (t/ha)	3298	52.6	44.6 bu/a
M-F-W-C	NT	4228	2070	37.0	33.7 bu/a

Rotation	Tillage	Biomass	Grain	Grain	Avg Yield
4-YEAR ROTATIONS CONTINUED		kg/ha	kg/ha	bu/a	(2 year)
18) W-M-C-F	RT	6010	2538	37.8	43.6 bu/a
M-C-F-W	RT	4337	2979	53.2	39.4 bu/a
C-F-W-M	RT	15.1 (t/ha)	152	2.4	19.7 bu/a
W-M-C-F	NT	2144	1453	21.6	35.2 bu/a
M-C-F-W	NT	4235	3144	56.1	53.7 bu/a
C-F-W-M	NT	21.6 (t/ha)	2046	32.6	31.7 bu/a
19) W-C-SAF-F	RT	4272	1641	24.4	36.8 bu/a
C-SAF-F-W	RT	23.3 (t/ha)	3477	55.4	44.1 bu/a
SAF-F-W-C	RT	5255	1358	26.9	17.1 bu/a
FLEXCROPPING					
20) FLEX(S.Wheat)	RT	2129	1079	16.1	1188 kg/ha (G)
FLEX(S.Wheat)	NT	2270	817	12.2	1406 kg/ha (G)

Symbols: ALF=alfalfa; C=corn; F=fallow; FLEX=flexible cropping; FM=forage millet; G=grass; M=proso millet; OP=oats + Tinga Pea; Pea=Austrian Winter Pea; SAF=safflower; SC=silage corn; SOY=soybean; SUN=sunflower; W=winter wheat

acceptable for 1992. The alfalfa and grass-legume treatments had low yields due to lack of water in 1992. These are only two-year results and do not necessarily reflect the rotational effects at this point. Variability between reps was less than in 1991, but still reflects the influence of previous cropping histories on the land that the study occupies. This variability should diminish with time as soil water levels become more reflective of the previous crop and rotation.

INTERPRETATION: This is the second year of yield data, therefore, no conclusions will be drawn at this time. Replication variability is expected to be much less with time. Crop yields in 1992 were very dependent on the amount of soil available water, especially the amount of soil water recharge that took place since the harvest of the previous crop.

FUTURE PLANS: All plots will be planted as planned for the 1993 crop year. A winter wheat-sunflower-fallow rotation will be added in 1993 because of the importance of sunflowers to the region due to the construction of a processing plant at Goodland, KS. Extra plots were added to the north end of the experiment to allow for future expansion.

CROPPED-LEVEL-TERRACES IN PASTURES

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PROBLEM: New sustainable farming strategies that use an "integrated resource management" approach incorporating livestock with cropping systems are needed. It is through this approach that the level of purchased inputs can be potentially reduced and crop outputs can be better utilized. For example, livestock contribute manure as crop input and grazing reduces harvesting losses and better utilizes the biomass produced. Other proven farming practices can also be used to improve the farming success and long-term sustainability. For example, annual cropping utilizes precipitation better than rotations involving fallow. Water harvesting techniques like bench terraces also improve soil water storage and crop water use efficiency. So combining level terraces, strip cropping within a pasture and annual cropping rotations with integrated crop and livestock practices should inherently be a good, successful and sustainable farming practice. However, this type of farming is no commonly used and little or no literature exists on the combination of these four technologies and their interactions. The objective is to evaluate the hydrology, crop growth characteristics, soil properties and the practical aspects of this type of farming.

APPROACH: Research plots were established on level terraces, bench terraces and on natural slopes (3% and 6%) that were constructed in a native grass field with a water contributing width above each plot equal to three times the width of each level terrace (most optimum width for the contributing slope). Other treatment variables include:

1. with or without deep chiseling to improve infiltration.
2. with or without cattle traffic to see the effect on infiltration.

Runoff flumes and recorders are installed each year to measure the amount of water that runs onto the plot area and off of the level terrace and the natural slope plots in order to evaluate the water harvesting aspects of the terraces and the plot treatments. Plots that have no water contributing area (by using a diversion) are also included and are necessary to evaluate the crop growth and water use with only normal precipitation levels. The plots will be replicated three times. Soil samples from the top 5 cm (2 in) were taken in 1991 for soil organic matter analysis, and will be repeated at the end of the project.

FINDINGS: <u>1990</u>: The terraces were constructed and plots established in May and June. The plots were planted to grain sorghum in June with poor emergence and yields (<1300 kg/ha (<20 bu/ac)) due to dry surface soil conditions. <u>1991</u>: Corn was planted no-till in the plots with 73 kg/ha (65 lb/ac) of nitrogen applied as starter with the planter and as NH3 side-dress chiseled. No rainfall was harvested during the spring and summer of 1991. Because of low rainfall after mid-June, potential grain yields were low so the corn was cut for silage August 22-23, 1991. Silage yields ranging from 6.7 to 19.9 Mg/ha (3 to 9 tons/ac), at

70% moisture content. Silage yields were only statisically different on the 3% slope. The bench terrace plot yields were statisically higher than the level terrace or natural slope plots. The chiseled subplot yields were statistically higher than the non-chiseled subplots. The deep-chisel subplots were deep chiseled to 38 cm (15") in the fall of 1991, as they were in 1990. The grass pasture was not grazed but the areas between the terraces were mowed and baled late June 1991. The 3% sloped area produced 1040 kg/ha (930 lb/ac) and the 6% sloped area produced 627 kg/ha (560 lb/ac) of hay. **1992**: Grain sorghum was planted no-till with no fertilizer applied. Dual and atrazine herbicides were applied for residual weed control, and paraquat was sprayed pre-emergence to kill any existing weeds. All plots were cultivated once 7-23-92. Grain sorghum yields were greatest on the bench terraces, with the chiseled plots on the level terraces only slightly less. Runoff was recorded from many rainfalls in 1992. Grain sorghum yields were greater on the 6% slope than the 3% slope for all plots. Yields were significantly greater on the bench terraces than those on the normal slope. During mid-June, the grass between the terraces was mowed and baled but only yielded 7 to 31 kg/ha (16 to 67 lb/ac). On 10-23-92, the chisel subplots were chisel-plowed 25.4 cm (10") deep, and the edges of the cropped areas and the terraces were mowed to prevent differences in snow catch between plots.
Maintenance: The bench terrace berms were sprayed with 2,4-D herbicide during early June 1991, late August 1991, mid-May 1992, and mid-June 1992 to control broadleaf weeds (mainly, wild sunflower).

INTERPRETATION: With the third year that the terraces and plots have been established, significant and real treatment or plot effects became apparent. Initially, the soil profiles were so dry that only half of the neutron access tubes were able to be installed in 1991. The rest of the tubes were finally able to be installed in 1992. In 1991, yields on the bench terraces were greater on the 3% slope, while in 1992 they were greater on the 6% slope. The water harvested in 1992 increased yields significantly. The yield data is similar to what was expected to occur. What was surprising is that it appears to have taken 3 years for soil water levels to get to "steady-state" conditions after initially being so dry below the grass. As an economic enterprise, a 3-year "start-up" may not be acceptable. However, the terraces being constructed right before the growing season in 1990 and no runoff in 1991 certainly contributed to the situation. Construction in the fall of the year and good runoff in the first crop year may have created good yields in the first crop year.

FUTURE PLANS: This project will be continued for at least two more years. Corn will be planted in 1993. Water runoff will again be measured with runoff flumes and recorders. Plans are to graze the pasture with cattle during the spring of 1992. Electric fencing will be used to block off ungrazed cropped areas for comparing infiltration differences with and without cattle. Infiltration rates will be determined with a sprinkler infiltrometer. Surface soil bulk density and crop growth characteristics (height, LAI, growth stage) differences will be measured.

WHEEL-RIDGE-TERRACE STRIP-CROP FARMING

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CRIS: 5407-13000-002-00D

PROBLEM: New farming techniques and strategies are needed that are sustainable. Cropping practices that use more spring and summer annual crops and use less fallow periods can better utilize the precipitation that falls in the west Central Great Plains. At Akron Colorado, almost two-thirds of the annual precipitation (82 year average) occurs during the late spring and summer months of May (3.04"), June (2.51"), July (2.67") and August (2.03"). The practice of fallowing the land, although saving moisture from an additional winter's snowfall and being a very successful long-time farming practice, has a low precipitation use efficiency (PUE) when compared to more intensive annual cropping.
Annual cropping with no fallow periods, on the other hand, is a marginal farming practice in this region due to the low total annual precipitation and is only successful with reduced tillage. However, reduced tillage farming may have more problems with weeds and may require more management. All of these concerns have been deterents to the adoption of reduced tillage farming. Therefore, a farming practice using annual cropping (to better use precipitation) but less constrained by the limited total precipitation could be potentially more successful than traditional crop-fallow rotations. Research in the late 60's and early 70's showed that water harvesting can increase total crop production per total area over conventional farming production during high precipitation years. The objective of this project is to determine if wheel-ridge-terrace farming is a more sustainable way to produce annual crops because of water harvesting and reduced crop area.

APPROACH: This project will use two separate sets of experimental plots, both using a randomized block statistical design. The two sets are:

1. A wheel-ridge-terrace (WRT) production area using three annual crops grown each year and replicated four times. Plot size is 30' x 100'. The WRT replaces the 2nd and 5th rows when using 6-row equipment, so that 2/3 of the land surface is cropped, and 1/3 harvests water. These plots were established the fall of 1990.
2. Soil profile comparison (SPC) plots to compare a) wheel-ridge-terraced, 4 of 6 rows cropped (W4), b) ridged-tilled, 4 of 6 rows cropped (R4) and c) conventional flat surface, 4 of 6 rows (F4), and d) 6 of 6 rows (F6) cropped are also used and replicated four times. Plot size is 15' x 120', and were established the spring of 1990.

Organic matter levels in the top 4 inches of soil will be measured in the cropped area before and after the project. Soil moisture content and crop water use will be determined using neutron access tubes. Crop growth characteristics will be monitored and recorded during the crop season. Crop grain yield and biomass production will be harvested and measured. Soil bulk density, fertility, and crop residue mass/cover will be measured annually. The plots will be chiseled to break up any compaction due to the terrace construction.

FINDINGS: Corn was grown in the SPC plots in 1991, and grain sorghum in 1992, and the respective grain yields and the two-year totals are:

		------ Grain yields (kg/ha) ------				
Year	Crop	W4	R4	F4	F6	L.S.D.
1991	Corn	3242a	2553ab	2187b	2009b	882
1992	Sorghum	2847ab	2937a	2182b	3341a	732
Both	Co.& Sor.	6089a	5490a	4369b	5351ab	1040

Yields followed by the same letter (a,b,c) are not statistically different. These yields are also on a total area basis. Note that corn yields in 1991 between the wheel ridges (W4) were significantly greater than flat surface skip-row farming (F4) and convention farming (F6). Combined two-year yields were significantly greater with W4 than F4.

Corn, soybeans, and sunflowers were grown in the WRT plots in 1991 and 1992. Corn population subplots were planted with 4 plant populations, and 2 varieties (91 and 100 day maturities). Corn grain yields on a total area basis ranged up to 5193 kg/ha (83 bu/ac). Optimum population was 33333 pl/ha (13333 pl/ac) on a total area basis, and 50000 pl/ha (20000 pl/ac) on a cropped area basis. Soybean grain yields averaged 891 kg/ha (13.3 bu/ac) in 1991, and 1294 kg/ha (19.1 bu/ac) in 1992, all on a total area basis. Of note was that 1992 was much cooler and less flowers were aborted as evidence by 3 to 5 pods per node in 1992 compared to 1 to 3 pods per node in 1991. Sunflower yields averaged 1219 kg/ha (1088 lb/ac) in 1991 and 1213 kg/ha (1083 lb/ac) in 1992, both on a total area basis.

INTERPRETATION: This study will determine if wheel-ridge-terrace annual crop farming is a practical and more profitable way of farming in the Central High Plains. The corn and soybeans appear to benefit from the water harvesting and wind protection aspects of the wheel ridges, as evident by much greater than normal yields on a cropped area basis. It would be preferable to have the wheel ridges farther apart so that less land is out of production but with the same benefits. In future research, I will use 3.3 m (10 ft) controlled wheel traffic, plant in narrower rows, and plant closer to the wheel ridge in order to have a much higher percentage of the total area cropped, which will improve total area yields. The corn population part of the WRT plots showed that corn populations on a cropped area basis need to be increased. This is significant because if plant populations can be as great as 50k pl/ha (20k pl/ac), then plant transpiration is a greater part of total ET. Corn populations less than this level have less than full cover leaf area, and have progressively more soil water evaporation as a percentage of total evapo-transpiration.

FUTURE PLANS: The SPC plots will be planted back to corn. The F6 plot in 1992 was split with 1/2 of the plot left fallow, so subsequent years data will have split plot yields for the F6 plots. The WRT plots will be crop rotated with corn after soybeans after sunflowers. Population subplots will be used with corn. Since the most benefit may be to low water stress crops like legumes, a legume forage crop will be added to the WRT plots along with a spring-cereal crop.

CROP RESIDUE DIFFERENCES WITH TILLAGE

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PROBLEM: Not enough data exists on the reduction and decomposition of crop residues due to time, tillage and weather factors. The Soil Conservation Service in Colorado has targeted this issue of crop residue changes through a season as an important issue for the proper determination of residue levels in regard to the Conservation Compliance program within the 1990 Farm Bill. As dictated in many individual farm conservation plans, 30 percent residue cover must be maintained. There is still much uncertainty as to what amount of tillage can be done between harvest of one crop and the planting of the next crop, and still maintain at least 30 percent residue cover during the high wind erosion period between November and April. Rainfall and the resulting surface soil moisture can have a significant effect on the rate of residue decomposition. Rates of decomposition determined in the climatically-wetter regions of the eastern half of the U.S. are probably not appropriate for the semi-arid regions of the western Great Plains. The objective of this project is to measure changes in crop residues for three crops, different tillage systems, and different rainfall levels (simulated with irrigation).

APPROACH: Corn, soybean, and sorghum residues currently exist within a solid-set irrigation system and will be used for this project. None of the cropped areas were tilled after harvest in 1991. Beginning residue levels (mass and percent cover) were measured. Plots were established across an irrigation gradient to simulate different rainfall water regimes. Different strips of tillage plots across the gradient were established as soon as possible during the spring of 1992. The corn and sorghum residues has tillage treatments of 1. chisel, disk (CD), 2. disk only (DD), 3. disk, sweep-plow (SP), and 4. sweep-plow only (SS). Note that the second letter is also the third and all subsequent tillage operations. The soybeans residues had tillage treatments of 1. disk, 2. sweep-plow and 3. untilled. The residue plots will not be cropped. Residue mass and percent cover are measured periodically during the year. Rainfall and irrigation amounts will be measured with catch cans. Specific details of the tillage operations (type, depth, speed,...) will be noted and recorded. Soil temperatures and moisture in the top 10 cm (4 in.) will be measured.

FINDINGS: The corn, soybean, and sorghum cropped areas were left untilled in the fall of 1991. Plots were established in the spring of 1992. Residue measurements were taken eight times from Apr. 14 to Oct. 19, 1992. The plots were tilled four times on Apr. 23, June 12, July 15 and Aug. 10. A gradient irrigation across the plots was applied May 12 and 26, and Sept. 14. For tillage treatments, plots were chiseled 25 cm (10"), disked 13 cm (5") or sweep-plowed 8 cm (3"). Soybean residues can be sweep-plowed one time and leave a little over 30% cover, but 1 disking left less than 10% cover. Grain sorghum residues can be sweep-plowed up to two times and still have greater than 30% residue cover.

Corn residues can be sweep-plowed up to three times and still have greater than 30% cover.

INTERPRETATION: The sweep-plow can be an emergency tillage tool for all three crops and still maintain adequate residues. The sweep-plow or undercutter could be a good alternative tillage implement for irrigated cropping systems because it could open up more options for timing herbicide and tillage operations.

FUTURE PLANS: Plans are to conduct these experiments for at least two years, in 1993 and 1994. The information will be made available to the SCS and will be published in agricultural journals.

DRILLED DWARF-CORN PRODUCTION STUDY

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CRIS: 5407-13000-002-00-D

PROBLEM: Dwarf corn varieties may provide another important alternative for dryland corn production in the west-central Great Plains region of the United States. Research on corn plant populations and grain yield is needed to determine optimum populations for dwarf varieties for this region. The characteristics of corn growth as a function of population, and the quantitative significance and sensitivity of the various yield components to grain yield needs to be measured also to understand how optimum yields are obtained. These varieties can be planted with a grain drill and combine harvested with a grain platform head, which has the economic advantage for traditional wheat farmers of not having to buy a row crop planter or a corn head for their combines. The agronomic growth characteristics and the practical, logistical aspects of farming dwarf corn varieties need to be evaluated.

APPROACH: In 1991, a dwarf corn variety, Cargill 1077 was grown with three traditional corn varieties, Pioneer 3732, 3733, and 3921. These 4 corn varieties have approximate times to maturity (black layer development) of 77, 100, 100, and 92 days, respectively. Row spacing for the traditional varieties was 0.76 m (30 in) and for the drilled dwarf corn variety was 17.8 cm (7 in).
In 1992, the Cargill 1077 variety was grown in two areas: 1. a population study with 4 populations located adjacent to CSU dryland corn variety trials, and 2. plots irrigated with a water gradient and with three populations.
These dwarf corn plots (except the irrigated plots) were located on land that was winter wheat the previous year, and were planted no-till into the standing wheat stubble. The corn was planted mid-May and also topdressed with at least 67 kg/ha (60 lb/ac) of N, as ammonium nitrate.

FINDINGS: <u>Standard varieties</u>: In 1991, two 100-day varieties yielded 3640 to 4000 kg/ha (58 to 64 bu/ac) for populations of at least 35,000 pl/ha (14,000 pl/acre). For these 2 varieties, grain yields were not significantly different for populations above 35,000 pl/ha (14,000 pl/ac) because the crop ran out of water due to small infrequent rains during mid-to-late summer. A 92-day variety had similar yields for the low and middle populations but had significantly higher yields of 4300 kg/ha (68.8 bu/ac) at 44,000 pl/ha (17600 pl/ac).
<u>Dwarf corn</u>: Overall, the Cargill 1077 dwarf corn has lower yields because it is a shorter season and therefore, has a lower yield potential. In the dryland plots, the lowest and highest populations in 1991 averaged 2800 kg/ha (45 bu/ac) and 3770 kg/ha (60.2 bu/ac) respectively, and in 1992 averaged 4402 kg/ha (70.2 bu/ac) and 4792 kg/ha (76.4 bu/ac) respectively. In 1992, the CSU dryland corn variety trials ranged from 4748 to 6767 kg/ha (75 to 108 bu/ac) with 6 varieties greater than 6272 kg/ha (100 bu/ac). The irrigated dwarf corn plots had yields ranging from 5515 kg/ha (88 bu/ac) to 7338 kg/ha (117 bu/ac), that received 3.8 to 19 cm (1.5 to 7.5 in) of irrigation. Other growth characteristics of the dwarf variety were:

Growth Characteristic	Dryland 1991	Dryland 1992	Irrigated
Ear length	5 to 15 cm (2 to 6")	7 to 14 cm (3 to 5.5")	13 to 15 cm (5 to 6")
Shank height	25 to 43 cm (10 to 17")	38 to 61 cm (15 to 24")	51 to 76 cm (20 to 30")
Leaf area index	2.1 to 2.35	---------	3.3 to 3.5

Single input economic analysis was conducted to determine where the marginal cost of the seed equaled the marginal revenue of the harvested grain. Seed cost averages $60 per bag of 100,000 seeds. In 1991, optimum final dryland population would have been 100 to 106 thousand pl/ha (40000 to 42500 pl/ac) for $2 to $3 corn. In 1992, dryland yields increased linearly with population so no optimum population could be determined. For the irrigated dwarf corn in 1992, optimum final population was 135000 pl\ha (54000 pl/ac). An interesting note is that many of the dwarf corn plants produced double ears at all populations.

Farming practices: In 1992, the dwarf corn was planted with a drill with a fluted metering cups and with 20 cm (8") opener spacing. Every other opening in the seed box of the drill was covered so that 40.6 cm (16") rows were planted in 1992. This drill and row spacing had much better seed distribution along the row, than in 1991 where a drill with a paddle wheel and gate type metering and 18 cm (7") row spacing was used. Because the ear shank height was so low in 1991, stubble heights were generally less than 10 cm (4") and much of the residue blew off the plots during the winter and snow depths were much less than in conventionally harvest corn rows. With no tillage after harvest, only 38% residue cover was measured in the spring of 1992.

INTERPRETATION: Based on 1991 results, the Cargill 1077 dwarf variety definitely needs to be planted at dryland populations of at least 112,500 pl/ha (45,000 pl/ac), but shows good potential as a alternative annual crop. The dwarf corn has an advantage of drying down much sooner. It was at 15 percent grain moisture content by Sept. 20, 1991 and averaged 12.3 % when harvested Oct. 1, 1991. However, 1992 was a much cooler summer and time to maturity of most crops was extended by as much a one month. The dwarf corn was planted in mid-May both years but in 1992 did not dry down to 15% grain moisture until Oct. 13.

Combine harvesting the drilled corn with a reel with parallel, vertical bats caused some of the ears to be knocked off the plant onto the ground, especially for ears that were still pointing upward. A more traditional reel with fixed bats and/or with wider bats, similar to those used for sunflowers, would probably cause less ears to drop. A sunflower head with pans with the same row and pan spacing may also reduce ear drop. New stripper-type grain heads could potentially be able to rack the ears off of the stalks and leave ear-shank standing residue heights in the field, which should greatly increase snow catch and reduce potential wind erosion.

FUTURE PLANS: The population plots will be repeated one more year with this dwarf corn variety. The results will be published in the regional popular publications, and in an applied agricultural journal.

IRRIGATED SOYBEAN YIELD AND WATER GRADIENT

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CRIS: 5407-13000-002-00-D

PROBLEM: Soybeans have been shown to be a poor dryland crop in the west central Great Plains due to poor water stress characteristics. Irrigated soybeans work well in a corn and soybeans rotation which has increased in popularity in the more traditional irrigated corn growing areas of eastern Colorado and western Nebraska and Kansas. However, the standard maturity groupings for soybeans do not adequately describe the maturities that can be realistically grown on the higher elevations of the western Great Plains. Much shorter maturities must be grown than predicted by the standard maturity groupings, which appear to be dependent upon not only latitude but also elevation. An estimate of maturity grouping for elevation is needed. Growth characteristics of soybeans for different maturities, populations and water (rainfall and irrigation) need to be measured and evaluated in order to determine optimum maturity lengths and populations for both dryland and irrigated situations. Seed quality can also be severely reduced in dryland soybeans. Yield component analysis can be used to determine these optimum maturities and populations, and the sensitivity of the components to final grain yield.

APPROACH: Four varieties of soybeans of different maturity lengths (Pioneer varieties 9162, 9202, 9241, and 9272 with relative group ratings of 1.6, 2.0, 2.4, and 2.7, respectively) were planted at four populations ranging from 275,000 to 500,000 plants per hectare (110k to 200k plants/acre) across a water gradient using a solid-set, line-source sprinkler irrigation system. There were 4 replications of each plot. Irrigation amounts were measured with catch cans across the irrigation gradient. Crop growth characteristics were measured during the growing season and included: growth stage, plant height, lowest pod height, numbers of nodes, number of pods, seeds per pod and stem branching. At harvest, seed samples were taken to determine seed quality (seed mass and number of green seeds). Yield component analysis as a function of maturity, population and water will be used to determine optimum maturity and population for both irrigated and dryland soybeans, and the minimum practical water requirement for dryland soybeans. Neutron access tubes were installed in the plots on the dryest and wettest sides of the irrigation gradient. Additional plots were planted to be used to validate the equations and modelled yield results. All soybeans were innoculated with nitrogen fixing bacteria prior to planting.

FINDINGS: Irrigation applied across the water gradient ranged from 29 to 180 mm (1.14 to 7.08") in 1991, and 27 to 111 cm (1.07 to 4.37") in 1992. Differences in plant height, number of nodes, branching, number of pods, number of seeds per pod, seed size, and number of green seeds were observed across the water gradient, maturities and populations. All of these parameters were measured from plant samples. In addition, growth stage and lowest pod height were observed and recorded in the field. A very apparent gradient effect was observed in the field in 1991. In 1992 because of the much cooler summer temperatures, only a small gradient effect was observed. However, the data will still be valuable because

it represents an extreme condition. Between the two years, a major difference was observed in the number of pods per node with one to three pods per node being typical in 1991, and three to five pods per node being typical in 1992. Because the gradient effect was very small in 1992, only the dryest and wettest plots across the gradient were analyzed for all of the yield components. Analysis of this data is still ongoing at this time. Conclusions will be made after the final years (1993) data is collected and analyzed. The validation plots were planted under a center pivot but were hailed out in June 1992.

INTERPRETATION: Soybeans like most legumes are not very stress tolerant crops as evident by the growth differences with water regime, and the seed production differences between 1991 and 1992. Using cultural practices like strip cropping between strips of taller crops could possibly reduce the heat and water stress effects on soybean growth and seed production. One growth characteristic where the stress effects really show up is in seed quality. When yields were less than 1200 kg/ha (18 bu/ac), seed size was greatly reduced. Plots with yields less than 600 kg/ha (9 bu/ac) had 25 percent smaller seed than over 1200 kg/ha yields.

FUTURE PLANS: This experiment will be repeated in 1993 with the same four varieties and populations across similar water gradient levels. A yield component model will be generated to predict yield components, the sensitivity of those components and final grain yields as a function of population, maturity length, and water amounts. Additional plots to validate the model will be planted again in 1993. This production model can then be used to do economic analyses and realistic decision making about the long-term sustainability and potential of dryland soybean production in the semi-arid regions of the west-central Great Plains.

IRRIGATED CORN POPULATION-YIELD STUDY

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CRIS: 5407-13000-002-00-D

PROBLEM: Many agronomic factors and cultural practices can influence corn grain yields. Grain yields can be maximized to near their potential if soil water and nutrients are not limiting plant growth and/or grain production. Maximum potential grain yields then become dependent on the genetic potential of each corn variety, and also dependent on the atmospheric conditions (i.e., heat units or growing degree days) received during the growing season. Plant damage by insects and disease can further reduce potential yields.

Cultural practices can have a direct and variable effect on actual final grain yields. Practices to minimize weed competition for water and nutrients help to maximize yields. Row spacing and plant populations have a direct effect on potential corn yields. Corn yields are increased 5-7% when row spacing is decreased from 102 cm (40") to 76 cm (30"), and are increased another 3-5% if row spacing is decreased to 51 cm (20"). However, 76 cm (30") has evolved to be the most common and practical row spacing when using large farm equipment.

Plant population is probably the most flexible cultural variable that affects final grain yield. Much uncertainty exists among irrigated farmers as to what is optimum plant population. Optimum plant population for each corn variety can be different. Even among varieties with the same maturity, optimum plant population can vary due to vegetative and reproductive growth differences. However, farmers will typically use a particular corn variety for many years. If the optimum plant population for a certain variety can be determined during the first 1 or 2 years of use, then at least that cultural variable becomes known and is no longer a worry or concern for the farmer. The objective of this project is to analyze the physical components of corn plants that determine final grain yield (i.e., leaf area, number of stalks, ears and kernels, and kernel mass) and how these components interact as a function of population. These component functions can then be used to determine optimum plant population, potential grain yields, and what components are most significant for producing high yields.

APPROACH: Three corn varieties (Pioneer 3779, 3714, 3475 with relative maturities of 98, 102, 106 days to black layer development, respectively) were planted at four different plant populations and replicated four times. The corn was grown at two sites on sandy loam and silt loam soils and was irrigated to fully replace crop evapo-transpiration losses as calculated by the modified Penman method with appropriate crop coefficients. Physical characteristics and yield components were measured and included leaf area at full cover and the following at harvest: stem count, ear count (1st & 2nd ears), number of rows and columns of kernels per ear (1st & 2nd ears), average kernel mass, yield, moisture content and test weight. The relationships between these variables were graphed, analyzed and mathematical functions developed for them. The functions are then used to predict grain yield, optimum plant population and to determine which components are most significant and critical to producing high yields.

FINDINGS: Analysis is ongoing for the yield component data from 1991 and 1992. The plots on sandy loam site were hailed out in June of 1992. Corn was planted at seeding populations of 55000 to 87500 plants/hectare (22000 - 35000 plants/acre). From the analysis so far, potential grain yields greater than 11900 kg/ha (190 bu/ac) are possible for the elevation and seasonal growing degree days near Akron CO. Optimum plant populations for irrigated corn can range from 67000 to 82000 plants per hectare (27000 to 33000 pl/ac). Water use efficiency, expressed as water/grain mass ratio, ranged from 570 to 700. Leaf area was not limiting for populations greater then 50000 pl/ha (20000 pl/ac) where leaf area index (LAI) values were greater than three.
Sensitivity analysis: The number of second ears goes to zero, and the ratio of first ears to stems approaches one as populations increase toward 75000 pl/ha (30000 pl/ac). The ratio of first ears to stems decreases with decreasing population due to more tiller stems. On the first ears, the number of rows of kernels (ear length) decreased with increased population. On the second ears, rows of kernels was essentially constant at 30 rows. Columns of kernels (ear diameter) was not dependent of population and had an average value of 15 for both first and second ears. Kernel mass was surprisingly not dependent on plant population and averaged 0.249 g per first-ear kernel and 0.199 g per second-ear kernel. Multiplying the actual data values of number of ears, rows and columns of kernels, and kernel mass together predicts grain yields within 10%.

INTERPRETATION: The most significant and sensitive component to grain yield is the number of first ears. For one of the varieties, potential grain yield was maximized at or greater than 75000 pl/ha (30000 pl/ac) because the number of second ears goes to zero and the ratio of first ears to stems approaches one. This information will allow component analysis and calculations to pinpoint the optimum stem population for maximum yields or maximum profits. Ear/stem ratio should decrease at higher populations because more of the primary stems do not produce ears.

FUTURE PLANS: Three or four other irrigated corn varieties will be used in 1993, to repeat this experiment at the same two locations. The results will be written up and presented at the national agronomy meetings, in a crop production journal, and as popular magazine articles.

CROP ROTATION AND TILLAGE EFFECTS ON WATER USE, WATER STRESS, AND YIELD OF ALTERNATIVE CROP ROTATIONS FOR THE CENTRAL GREAT PLAINS

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PROBLEM: Increased use of conservation tillage practices has made more soil moisture available for crop production in the central Great Plains, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Precipitation timing and amounts exhibit wide variation from year to year in this area, producing variation in timing and severity of water stress. Information is needed regarding water use patterns, rooting depth, evapotranspiration/yield relationships, and water stress effects of crops grown in proposed alternative rotations for the central Great Plains. The specific objectives of this experiment are to quantify the following quantities for alternative crop rotations and compare them with those obtained from conventional wheat-fallow:

1. Water use amounts during vegetative, reproductive and grain-filling growth stages
2. Depth of water extraction
3. Water stress during vegetative, reproductive and grain-filling growth stages
4. Water use-yield relationships
5. Long-term water balance and precipitation storage and use efficiencies
6. Long-term water movement in the soil that could move pesticides and fertilizers into ground water

APPROACH: Seven rotations (see Table 1) are used for intensive measurements of water use and water stress effects on yield. The seven rotations were selected over others because of the hypothesized differences in rooting depth, water extraction ability, water requirement, and sensitivity to water stress. FLEX plots were planted to spring wheat in 1992 (following corn in 1990 and grain sorghum in 1991). Measurements of soil water content are taken at two locations in each plot at weekly intervals using a neutron probe at depths of 0.15, 0.45, 0.75, 1.05, 1.35, and 1.65 m. Soil water content in the 0-0.30 m layer is also determined by Time Domain Reflectometry. Precipitation is measured adjacent to the plot area episodically. From these measurements, evapotranspiration is calculated by the water balance method, and rooting depth is estimated from observations of soil water depletion.
An infrared thermometer is used to measure canopy or leaf temperatures, and a psychrometer is used to measure wet and dry bulb air temperatures as often as possible during the growing season when clear skies prevail. These measurements are used to calculate the Crop Water Stress Index (CWSI) to quantify water stress. Net photosynthesis rate, transpiration rate, and stomatal conductance are measured weekly at midday on six leaves of each plot in the second replication using a portable photosynthesis system.

Leaf area index, crop height, and plant growth stage are measured weekly to quantify water stress effects on plant growth and development. Final grain yields are taken to quantify water stress effects on plant productivity.

FINDINGS: Table 1 shows a summary of the data collected in 1992 in a greatly reduced form, but trends are still evident. Poor stands of winter wheat developed as a result of low or no fall emergence following planting into very dry soil in the fall of 1991. The result was low leaf area development, which was further reduced by low precipitation during April and May. Water stress was at high levels during all vegetative and reproductive stages, but decreased somewhat during grain-filling due to June rainfall which was about 50% above normal. For the entire growing season, wheat following millet was under greater water stress than the wheat on fallow due to the differences in starting soil water content. Wheat following millet used about 20% less water as evapotranspiration than wheat on fallow, due to this difference in stored soil water, higher water stress, and lower leaf area. Relative yields followed the relative evapotranspiration amounts, with the lowest yields obtained on the wheat following millet rotations. Yields on all wheat rotations were much lower in 1992 than in 1991 due to the poor stand establishment and lower growing season precipitation.

The safflower crop suffered low levels of water stress until the middle of July. Then levels of water stress were moderate through late flowering and grain-filling, as the available soil water was used up by the large leaf area developed during the favorable precipitation conditions of June and early July. Safflower yields were approximately double the 1991 yields.

The favorable distribution of precipitation through June, July, and August helped to keep water stress levels in millet, sunflower, and corn low through most of the vegetative and reproductive stages, with fairly good leaf area development in all of these rotations, except the corn following sunflower (really corn following millet due to stand failure of the 1991 sunflowers), which showed restricted vegetative development due to low soil water content at planting. Yield/water use functions were similar to previously acquired data for wheat and corn.

INTERPRETATION: The 1992 data demonstrate the effectiveness of the more intensive rotations in taking advantage of the favorable precipitation pattern that occurred this year. The corn crops following wheat especially showed good production because of the timeliness of the rainfall. The rain that fell during these months was used more effectively in grain production than it would have been in recharging a fallow soil profile, when precipitation storage efficiency was around 20%. The yield/water use function for corn shows that the June, July, and August precipitation was responsible for producing over 4000 kg/ha of corn grain.

FUTURE PLANS: Water use, water stress, yield, rooting depth, height, leaf area, and growth stage measurements will continue to be made next year. The leaf photosynthesis, transpiration, and water potential measurements, as well as the planned expansion of all measurements into more rotations will be discontinued to provide time and resources for studies of alternative crops. We still have

plans to use the data collected in this study to validate the model EPIC and run long-term (20 year) scenarios of production under various rotations using Akron weather records as a means of assessing the viability and potential of various crop rotations for this area.

Table 1. Summary of yield, cumulative evapotranspiration (CET), starting spring soil water content, maximum leaf area index (LAI), average seasonal Crop Water Stress Index (CWSI) for selected alternative crop rotations, 1992.

Crop	Rotation	Yield (kg/ha)	CET (cm)	Date of Starting Soil Water	Starting Soil Water (cm/120cm)	Maximum LAI	Average CWSI
Wheat	WF (NT)	2341	30.8	02 MAR 92	15.9	1.41	0.62
Wheat	WF (CT)	1808	30.0	02 MAR 92	12.4	1.07	0.56
Wheat	WCF (NT)	2141	32.1	02 MAR 92	16.1	1.20	0.62
Wheat	WCM (NT)	591	24.5	02 MAR 92	8.5	0.51	0.88
Wheat	WSAFM (RT)	591	25.2	02 MAR 92	8.2	0.48	0.76
Spring Wheat	FLEX (RT)	952	28.0	02 MAR 92	11.0	0.81	0.69
Corn	CFW (NT)	5215	41.5	05 JUN 92	17.7	2.03	0.32
Corn	CMW (NT)	5186	40.6	05 JUN 92	18.6	1.99	0.31
Corn	CSUN (RT)	1723	32.7	05 JUN 92	13.3	1.83	0.49
Millet	MWC (RT)	2021	23.0	07 JUL 92	14.8	2.49	0.48
Millet	MWSAF (RT)	1611	20.5	07 JUL 92	12.1	1.82	0.43
Safflower	SAFMW (RT)	1417	40.6	07 APR 92	17.3	4.00	0.32
Sunflower	SUNC (RT)	1232	31.5	18 JUN 92	11.6	2.93	0.36

WF=wheat-fallowCFW=corn-fallow-wheatMWC=millet-wheat-corn
WCF=wheat-corn-fallowCMW=corn-millet-wheatMWSAF=millet-wheat-safflower
WCM=wheat-corn-milletCSUN=corn-sunflowerSAFMW=safflower-millet-wheat
WSAFM=wheat-safflower-milletNT=no till
CT=conventional till
RT=reduced till

FIELD EVALUATION OF CORN CROP COEFFICIENTS BASED ON GROWING DEGREE DAYS OR GROWTH STAGE

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CRIS: 5407-13000-002-00-D

PROBLEM: Corn evapotranspiration (ET) can be predicted from models based on weather parameters. These models predict a potential ET which is then multiplied by a factor (the crop coefficient) to give estimated ET. Crop coefficients currently in wide use for corn are based on time indexed from date of planting and date of full cover. These time-based coefficients work well under average planting dates and growing season weather conditions, but require periodic adjustment when non-average conditions occur. Crop coefficients for corn based on growing degree days or growth stage can automatically adjust for differences in growth due to non-average weather conditions. The objective of this experiment is to determine if previously defined corn crop coefficients (from Nebraska) based on growing degree days (GDD) or growth stage (GS) are applicable to corn grown in northeastern Colorado, and if these coefficients produce more accurate predictions of corn ET than traditional time-based (ARS) coefficients.

APPROACH: Three varieties of corn (Pioneer hybrids 3902, 3732, and 3540, with days to black layer of 91, 101, and 109, respectively, and GDD to black layer of 2445, 2559, and 2645, respectively) were planted on three dates (30 Apr 92, 19 May 92, and 10 Jun 92) to a final plant population of about 69,100 plants/ha with 4 replications of each planting date/hybrid treatment. ET was calculated by the water balance method using measurements of soil water content (by neutron probe and TDR), precipitation, and irrigation water applied. Irrigations were applied weekly by overhead sprinklers to replace water lost from the top 120 cm of the soil profile. Reference crop (alfalfa) ET was predicted by the Kimberly Penman method using weather data collected by an automated weather station located approximately 400 m from the plot area. Reference ET was adjusted to corn ET by three methods:
Method 1. Time-based ARS-Jensen crop coefficients
Method 2. GDD-based crop coefficients from S.E. Hinkle et al.
Method 3. GS-based crop coefficients from S.E. Hinkle et al.
These values of ET were then compared to water-balance-computed ET.

FINDINGS: The 1992 results agree closely with the 1991 results, with the GDD- and GS-based crop coefficients predicting corn ET better than the ARS time-based coefficients both before and after silking for most of the planting date-hybrid maturity combinations. Additionally, most of the corn ET estimates from the GDD- and GS-based crop coefficients were within 10% of measured ET values.

INTERPRETATION: Temperature has been previously shown to be the primary climatic variable controlling the vegetative growth of corn that has adequate water, nutrients, and light. Consequently, predicting ET using models based upon an actual crop-growth parameter (growth stage) or a climatic crop-growth-response variable (temperature) has a better basis than time for the dependent variable for crop coefficients. No additional work is required for Method 2 because

maximum and minimum temperature are already required to calculate reference ET. The estimation of full cover date and the sometimes uncertain interpretation of actual full cover are also eliminated. Method 3 would require that growth stage be observed at least weekly for each field, but this method is intended to be used only if total GDD for a particular variety in a particular region is not known, then switch to Method 2 when a good value for total GDD is known. Farmers are very receptive to methods that are based on GDD because of an inherent understanding of the close relationship between crop development and temperature, and because of the ease of GDD methods.

FUTURE PLANS: No further data will be collected. The results will be submitted for publication. Because hourly temperature data were collected during this project, a GDD vs, Growing Degree Hour (GDH) analysis will be made to further refine the accuracy of the corn crop coefficient equations, and subsequent corn ET prediction. This analysis may also increase the understanding of the air temperature and corn growth interrelationship.

RIDGE-PLANTING TEMPERATURE EXPERIMENT

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CRIS: 5407-13000-002-00-D

PROBLEM: The Central High Plains growing season is significantly shorter than in other regions at similar latitudes due to higher elevations. R. E. Neild found that across Nebraska, there was a 0.87 C decrease in temperature for 1 degree increase in latitude and a 0.52 C drop in temperature for a 305 m increase in elevation. Higher land elevations exhibit lower overall air and soil temperatures throughout the spring-to-fall growing season. For corn grain production, 100-105 day relative maturity varieties are grown near Akron CO at 1420 m elevation, as compared to 115-120 day varieties grown in southeastern Nebraska below 400 m elevation. The effects of higher elevations on decreasing soil and air temperatures can be potentially offset to some extent by microclimate modification of the soil. Soil formed in ridges typically warms up sooner, both daily and seasonally, than flat soil surfaces due to more effective interception of incoming solar radiation. The warmer soil could allow for earlier planting and more rapid germination, and could speed early phases of crop development by increasing air temperatures at the soil surface. Consequently, longer season varieties with greater yield potential could be grown in this area. The objectives of this experiment are to determine:

1. if time of emergence can be shortened with ridged row crops
2. the growing degree day requirements for corn and sorghum emergence
3. the management factors of ridge farming.

APPROACH: This experiment was initiated in 1989 using corn grown under sprinkler-applied, full irrigation. Grain sorghum and corn were grown in 1990, and grain sorghum only in 1991 on silt loam and sandy loam soils. Both split plot and randomized complete block experimental designs are used with four replications. Soil and air temperature near the soil surface were measured for different tillage and residue treatments. The soil treatments were:

1. no-till, standing corn stubble, flat surface, north-south rows (SS)
2. ridged corn stubble, north-south rows (RS)
3. clean tilled, some residue, flat surface, north-south rows (B)
4. clean tilled, some residue, rows ridged north-south (R)
5. " " " " " " east-west (REW).

Row spacing was 0.76 cm (30 in.). Soil temperature (5 cm below soil surface) and air temperatures (10 cm above soil surface) were measured with thermocouples and recorded with an automated Campbell 21X data logger at 1-minute intervals during each day for the period from planting until mid-July (full canopy development). The crops were planted directly on the ridges. Three planting dates (early May, mid-late May, early June) were used to check for any time-of-year temperature differences. Hours from planting to emergence, plant height and vegetative growth stage were monitored to determine microclimate effects on germination and plant development rates. Residue (mass per area and percent cover) were measured

prior to planting. Soil moisture in the top 5 cm (2 in) was measured at least weekly prior to planting and during early vegetative development because soil temperatures and heat movement through the soil surface can be directly affected by soil moisture content.

FINDINGS: Soil temperature profiles were measured with 5-TC arrays placed at depths of 10, 5, and 2.5 cm and on the soil surface in the R, B, RS, and SS treatments in May and June of 1992. These data will be used to quantitatively adjust the previously acquired soil temperature data from 1991 to account for the differences in planting depth among the tillage treatments (following the method of S. Gupta).

INTERPRETATION: The soil temperature profile data have not yet been analyzed, so the temperature adjustments have not been made. No interpretation possible at this time.

FUTURE PLANS: Final results will be published in scientific journals and as popular articles in farm magazines.

SUNFLOWER STUBBLE, WIND VELOCITY PROFILES

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CRIS: 5407-12130-003-00-D
5407-13000-002-00-D

PROBLEM: Sunflower is an economically viable crop for dryland crop rotations in the central Great Plains. However, concerns about wind erosion during the summer fallow period following sunflower harvest arise due to the assumed low residue amounts left by sunflower after harvest, resulting in inadequate protection for the soil surface against wind erosion.
Wind erosion estimates within sunflower residues in the west-central Great Plains are questionable with existing data and estimation methods. Research done by ARS scientists while developing a wind erosion model have discovered calculated soil losses by wind from the traditional Wind Erosion Equation (WEQ) may significantly underestimate soil losses in the western portion of the Central Great Plains. Quantitative wind velocity data is specifically lacking for sunflower residues in this region of the U.S. More accurate estimates of soil loss by wind will be possible using the new wind erosion model if wind velocity data for sunflower residues are obtained. The ability of sunflower residues of varying height and stalk densities to trap snow needs to be quantified, as well as the resultant changes in over-winter and spring soil water content to assess the production potential of dryland sunflowers grown in crop rotations in this region. Development of quantitative data regarding actual reductions in wind velocity and increases in snow catch and soil water due to managed sunflower stubble will encourage farmers to diversify cropping systems to include sunflower.
The specific objectives of this study are:
1. Measure wind velocities and residue amounts within sunflower residues at various heights above the soil surface for:
   A. two standing, non-tilled, sunflower stalk heights,
   B. three plant populations, and
   C. sunflower residue conditions after various tillage operations, including sweep-plowing, disking, and no tillage, with and without standing wheat stubble from the previous winter wheat crop.

2. Measure snow depth differences that occur in response to the residue management treatments outlined above.

3. Measure changes in soil water content that occur over winter and spring in response to the residue management treatments outlined above.

APPROACH: Plots with approximate dimensions of 45 m by 45 m (150′ by 150′) will be established to minimize border effects on wind velocity and snow catch, and to allow measurement of wind velocity from all wind directions. Oil-seed sunflowers will be planted in 0.76 m (30") row spacing at 32100, 37100, and 61800 plants/hectare (13000, 15000, 25000 plants/acre) . At harvest, plants will be cut to leave standing stalk heights of approximately 0.30 and 0.60 m (12" and 24"). One set of plots will have stalk heights flattened with a roller after harvest. Wind velocities will be measured with micro-response, cup anemometers

at 2 m (6.5') above the soil surface and at 6 heights within the standing stalk residue to obtain wind profile data. Wind direction will be measured at 2 m (6.5') with a wind vane. Stalk heights, densities, diameters, residue mass and percent cover will be measured after harvest and fall tillage operations. Soil water content will be measured after harvest and periodically throughout the winter and spring using neutron scattering and time domain reflectometry techniques. Snow depth will be measured following each snowfall and/or period of high wind with potential for drifting.

FINDINGS: The plots were planted in the spring of 1992, but had erratic germination. We obtained cooperation of a local farmer (Rick Lewton) in cutting areas of one of his fields of sunflower to specified heights. This field's plant population was similar to our proposed low population. We obtained wind reduction, snow catch, and soil water content data on three sites within this field (stalk heights of 43 and 73 cm, and stalks laid down flat). The 73 cm and 43 cm stalk heights slowed the wind near the soil surface by 46% and 27%, respectively, compared to the wind speed at the same height above the flattened stalks. The stalks of both cutting heights trapped approximately twice the depth of snow as the flattened stalk area did.
A regression model describing wind velocity within the sunflower stubble as a function of the wind velocity at 2 m above the soil surface and height of sunflower stalks explained 94% of the observed variation in wind speed. At this low plant population wind direction relative to row direction did not have an effect on wind velocity withing the standing stalks or near the soil surface. The regression model is:

$$U_z = 0.720 - 0.279*U_2 - 1.09*H - 0.082*\ln(z) + 0.250*\ln(z)*U_2$$

where U_z = wind velocity (m/s) at height z (cm)
U_2 = wind velocity at 2 m above the soil surface
H = height of sunflower stalks (m)

INTERPRETATION: Standing sunflower stalks are effective at reducing wind speed at the soil surface, and increasing snow catch, thereby reducing the potential for wind erosion and increasing precipitation storage efficiency.

FUTURE PLANS: Residue measurements will be made on the Lewton plots in the spring, as well as final spring soil water content measurements. Some measurements of wind velocity will be possible on two areas of sunflower on the station plots that had sufficient emergence. These measurements will commence after snow melt. The experiment will be repeated with all combinations of stalk height, population, and tillage during the 1993 growing season.

NITROGEN RESPONSE OF SPRING AND WINTER CANOLA

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CRIS: 5407-12130-003-00-D

PROBLEM: The United States currently imports over 600 million lbs of canola annually. This represents a potential production acreage in the United States of approximately 300 to 400 thousand acres. Canola has been identified as a potential oilseed crop for the central Great Plains. The question is whether canola can be successful and sustainable in the Central Great Plains. Much of the basic agronomic knowledge required to make canola a successful option in the Central Great Plains is uncertain. Basic management information such as variety selection, nutrient requirements, heat unit requirements, planting date and planting depth have not been established for canola in our region.

APPROACH: In this study the N response, and yield potential of 4 spring varieties (Westar, Parkland, Tobin, Global) and 3 winter varieties (Touchdown, Glacier, Crystal) are being evaluated in a split-block designed field experiment with 4 replications with varieties as main plots and nitrogen (N) rates (0, 40 and 80 lbs N/acre) as subplots (strip-plots). Individual experimental units are 30 (9.144m) by 50 (15.24m) ft. The experiment is established on a Platner silt loam under two different previous crop-management histories at the Akron Research Station. Site one is established in wheat stubble, site two is established in fallow ground previously planted to dryland corn.

On August 15, 1991 all plots were top dressed with 40 lbs P_2O_5 as 0-46-0 and N (N as ammonium-nitrate) treatments were applied at this time. All fertilization was done using a Barber spreader. Winter varieties were first planted on August 30, 1991, in moist soil caused by a half inch rain on August 28, 1991. Because of dry conditions following planting most of the canola that germinated was dead by the first week of October. Winter varieties were replanted October 9, 1991, 1 inch deep, at a seeding rate of 6.5 lbs of seeds per acre (approximately 650,000 seeds/acre) using a Tye no-till-disk drill. Spring varieties were planted when surface soil temperatures reached an average temperature of 4°C (39.2°F) on March 31 the last week of March or the first week of April 1992 depending on soil moisture conditions.

On 2 september 1992 the second year of the experiment was established and fertilized. Winter varieties were planted on 3 September 1992 in both fallow and stubble-back plots. In 1992 treflan was applied (1 lb a.i.) preplant with a granule applicator attached to a sweep plow with mulch treaders. At planting 30 lbs P_2O_5 per/acre was applied as 0-46-0 with the seed.

FINDINGS: The best yields were measured at the 80 lb N rate with Spring varieties in the plots established in fallow (1400 lbs for the Variety Westar). On average a yield advantage of about 500-600 lbs of grain was measured in the fallow verses stubble plots regardless of variety. At $0.10/lb that would be a $50-60 difference in gross returns. Pre-plant soil water contents were only 0.3 inches greater in the fallow plots so yield differences can not be attributed to differences in stored soil water. In general we observed a weaker stand in the stubble plots as compared with the fallow plots. Also, we observed greater weed

pressure in the stubble plots as compared with the fallow plots. The primary problem weeds were downy brome, volunteer wheat, russian thistle, and Kochia. The unusually cool summer undoubtedly allowed the canola to mature adequately and made for a long grain filling period. A second year of data will help us to determine if we were lucky (or not) and will give us a better estimate of the true yield potential for this crop in our region.
The record low temperatures of the last week of October 1991 were severe enough to have damaged and/or eliminated much of the winter canola production from Colorado to Montana (Personal Communication Dr. Duane Johnson CSU). The 1992-93 crop of winter canola looks good on the fallow ground but failed to emerge in time to harden for winter in the stubble plots.

INTERPRETATION: The spring varieties show potential in our part of the Central Great Plains. For the stubble-back planted plots to be successful we will need to control the annual grasses. The winter varieties are more difficult to get established. We have had two failures with the winter varieties on the stubble plots. Whereas the winter varieties planted into summer fallow the fall of 1992 look good. That is the stand was adequate and the plants were large enough to harden and should survive the winter.

FUTURE PLANS: We would like to continue the experiment for a total of at least 3 years as a measure of environmental variability.

INVESTIGATION OF BASE TEMPERATURE AND PLANTING DEPTHS OF SPRING CANOLA AND SAFFLOWER

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PROBLEM: Canola and safflower have recently been identified as potential alternative crops for the Central Great Plains. Very little information exists in the literature concerning the heat unit requirements for their growth, development, and production. An understanding of the match between their physiological heat unit requirements and the historical record of a given crop producing region will aid in the successful match and development of appropriate varieties and management practices for a given region. Quantification of the heat unit requirement for germination and physiological development of canola and safflower can be used to help guide producers, researchers and extension personal in making informed management decisions with respect to optimal spring planting dates, time of expected seedling emergence, time required for the onset of flowering, and the onset and duration of the grain filling period. The heat unit quantification of canola and safflower can potentially aid in the selection of the proper variety for a given location in the Central Great Plains and aid plant breeders in the selection and development of appropriate genetic material for a given location. The objectives of this study are to develop models to predict seedling emergence characteristics as a function of soil temperature and planting depth, and to provide data for the development of heat unit requirements for the germination of these crops. Models will be used as an aid to guide producers in early season management of these crops.

APPROACH: In this first of a series of potential investigations we examined the amount and rate of germination of two spring canola varieties (Tobin and Global) and one safflower variety (S-208) as affected by planting depth and temperature. Individual 500 ml clear plastic pots were marked and filled with soil at a wet bulk density of 1.0 with either Platner silt loam or Weld silt loam. The experiment was conducted at constant soil water contents of either 16 or 20 percent gravimetric water content. Individual pots marked at various depths were partially filled with moist soil to a specified mark on each pot. Twenty seeds were placed at equidistant spacings on the surface of the soil and then covered with soil to the appropriate depth. Seeds were planted at 5 different planting depths of 1, 2, 2.5, 3, or 4 cm (one depth and variety per plastic pot). A complete replication of one soil type at one soil water content consisted of 40 pots (2 varieties, by 5 planting depths, by 4 temperatures). The appropriate individual pots were then placed into separate constant temperature incubators at 4, 8, 12, and 16°C (39.2, 46.4, 53.6 and 60.8°F) which corresponds to early spring temperatures in the Central Great Plains during the months of March and April. The complete experiment was replicated 2 times. The number of seeds germinated in each pot were counted on a daily basis initially and then twice daily during the rapid germination phase at 16 and 12°C. Germination measurements and accumulated heat units were determined for a 55 day period from December 17, 1991 to February 12, 1992.
We repeated the experiment for the same varieties Global and Tobin at 0, 2, 4,

and 16°C. Three additional varieties were included in this second experiment these were Alto, Crystal, and Glacier.

FINDINGS: From these two experiments we found that the base temperature for canola is very near 0°C (32°F). Essentially no emergence was observed at 0°C. We also found that regardless of the constant temperature regime imposed that emergence begins at between 1500 and 1800 growing degree hours (GDH) for the spring varieties Global, Alto and Tobin at the 1 cm planting depth. For the winter varieties we found that 1800 to 2700 GDH were required to emerge. Germination of canola was essentially complete for all depths 12 days after planting at 16°C, 22 days after planting at 12°C, 30 days after planting at 8°C, and 47 days after planting at 4°C. We measured up to 95% germination at the shallower depths at 16°C by day 12 with an average of near 68%, at 12°C we measured up to 90% germination at the shallower depths with an average near 65% by day 22. At 8°C we measured up to 70% germination with an average of 50% on day 30. At 4°C we measured up to 60% germination with an average of 20% by day 50.

INTERPRETATION: Preliminary analysis indicates we might expect severe reductions in stand when canola is planted at soil temperatures that will be sustained much below 8°C. This preliminary analysis suggest that spring canolas should be planted not much earlier than the last week of March and that increased seeding rates may help to off set the expected loss in stand if planted earlier when temperatures are cooler. Preliminary observations of safflower suggest similar trends.

FUTURE PLANS: We have found that canola and safflower will germinate at temperatures of 4°C. The study is complete and will be put into manuscript form within the next year.

CARBON AND NITROGEN MINERALIZATION FROM DECOMPOSING CROP RESIDUES

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CRIS: 5407-12130-003-00-D

PROBLEM: The amount of NO_3-N entering groundwater supplies is a national concern. The NO_3-N entering ground water comes from N mineralized from native soil organic matter, organic amendments, crop residues, and from fertilizer applied in excess of the amount required for sustainable crop yields. The excess NO_3-N (particularly the mineralized NO_3-N) is not always in synchronization with maximum crop uptake and is therefore potentially leachable. Most laboratories recommending N fertilizer either ignore or simply guess at the amount of N mineralized from organic sources. The problem lies in the complexity of N turnover which is affected by variable soil, and residue characteristics, and variable soil environment from year to year. Simulation models which mimic the processes of organic N turnover, crop N uptake, and soil water movement, allow for the integration of variable residue, soil, and environmental factors and can be used to predict these processes.

APPROACH: The objective of this study is to evaluate and improve existing simulation models to accurately predict: (i) seasonal N dynamics under field conditions. (ii) available N in synchronization with crop uptake (iii) N available for leaching. The MINIMO subroutine (The mineralization immobilization subroutine for the EPIC, and CERES-maize models) has been tested for its ability to mimic the mineralization of N from ^{15}N-labeled crop residues under field conditions. In those studies the simulation model over predicted the amounts of N mineralized. Rate constants for decomposition of plant materials in MINIMO have been derived from laboratory studies with finely ground plant materials mixed with soil. Crop residues decomposing under field conditions are usually not finely ground. The over prediction may partially be related to rate constants in MINIMO. Laboratory investigations of N mineralized from the surface soil of a typical Platte Valley soil mixed with corn residues of variable N concentration and 5 particle sizes has been under way since June of 1990. Residue soil mixtures are incubated and periodically leached with 0.01 M $CaCl_2$ using a modified Stanford and Smith approach. The collected data will be used to modify the MINIMO model to take into account crop residue condition in the field (i.e. stalks chopped vs disked, or left on the surface).

FINDINGS: The amount of N mineralized (as measured by the accumulated inorganic N) decreased with decreasing residue particle size for corn leaf residues (C/N ratio of 25). This relationship between leaf particle size and the amount of inorganic N accumulated was consistent for all 4 particle sizes. For leaf particles ground to less than 2 mm, only 25% of the residue N was recovered 174 days after residue incorporation. For larger leaf particles 40 mm long by 10 mm wide up to 75% of the residue N was recovered 174 days after residue incorporation. For corn stalk particles (C/N ratios of 65 to 70) we measured net immobilization during the entire 174 day incubation. Less immobilization was measured for the largest corn stalk particle sizes. A follow up study was designed to look at microbial biomass pools and denitrification. This study has

not been completed primarily due to not yet having the lab set up at the Akron station for measuring CO_2 and N_2O from closed containers. At the present time a procedure for measuring NH_4-N from $CaCl_2$ leachates has been developed at the Akron station. The other methods, hardware, and procedures for doing this type of work have been developed for the Akron station and the study will be conducted this spring (1993).

INTERPRETATION: Even though the actual amount of accumulated inorganic N was less with the smaller particle sizes we suspect that the actual decomposition of the smaller residue sizes was greater. It is reasonable that the greater surface area with the smaller particles would provide a greater opportunity for microbial attack. We suspect that much of the N not accounted for during this decomposition may be either immobilized as microbial N or lost through denitrification. Denitrification is supposed to be minimal at water filled porosities less than 60%. This experiment was conducted at water filled porosities of 55% or less. However it is possible that the soil micro-environment around individual particles may go anaerobic if decomposition proceeds rapidly enough. This would void the 60% water filled porosity rule of thumb for the decomposition of crop residues of sufficiently small size.
The wide C/N ratio of the corn stalk residue resulted in net immobilization for 174 days at optimum moisture and near optimum temperature. From other research we have conducted we know that decomposition under field conditions in the midwest proceeds approximately 30 to 50% slower than under laboratory conditions. Under field conditions a net immobilization of corn stalk residues may be for a year or more.

FUTURE PLANS: Follow up research will be conducted to quantify the amount of denitrification in this system. We will continue additional incubation experiments designed to determine the amount of N that has been converted to microbial biomass N and the amounts of CO_2 produced during decomposition. The final step will be to run this data through the simulation model to further test its ability to accurately simulate the measured N transformations and residue decomposition. The developed relationships will be used to improve the existing simulation model which will then be tested under field conditions for its ability to accurately quantify N and C cycling in Great Plains soils. A final test would be to use the model to improve existing fertilizer recommendations which at this time do not accurately take into account the cycling of C and N.

AN EVALUATION OF NITRIFICATION INHIBITORS AND PRECISION PLACEMENT OF LARGE UREA PELLETS FOR IRRIGATED CORN

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CRIS: 5407-12130-003-00-D

PROBLEM: Efficient use of fertilizer N sustains crop yields, reduces producer expenditures for fertilizer, and minimizes environmental contamination. Recent research with irrigated corn in Colorado and wheat in North Dakota has shown significantly improved N fertilizer uptake when the nitrification inhibitors CaC_2, and DCD (dicyandiamide) are mixed with urea. In Kansas with cool season grasses, large urea granules significantly increased N uptake when compared with conventional urea fertilizer. Research done in Texas where fertilizer N was placed only in the non-irrigated rows of irrigated crops showed greater N recovery and therefore less potential for N leaching losses than conventionally placed fertilizer N. In this study a combination of these products and placement strategies are being tested to maximize the fertilizer use efficiency of irrigated corn.

APPROACH: The objective of this study is to determine the best combination of inhibitor and fertilizer placement in the non-irrigated row for irrigated corn to increase N use efficiency and reduce fertilizer N lost to leaching. The study was initiated the spring of 1990 on a Hall silt loam near Shelton, Nebraska at the MSEA site. Large 1.7 g urea pellets were placed 10 cm deep and 10 cm away from rows of V1 stage corn (1990) and V3 stage corn (1991) at 20 cm intervals along the row. Nine treatment combinations of large urea pellets with or without two nitrification inhibitors (CaC_2, or DCD) were applied at N rates of 40, 80, or 120 kg N/ha. Conventionally banded urea and a check with no fertilizer applied were also included in the experiment. Microplots within larger field plots were established at all treatment combinations for the 40 and 120 kg N/ha rates. These received ^{15}N labeled urea to allow for estimation of fertilizer N recovery and plant N derived from fertilizer. Inorganic N levels in the zone of fertilizer application were monitored 7, 32, 43, and 96 days after fertilizer application. Chlorophyll meter readings, leaf punch N, total plant N, and total plant dry weights were measured 30, 34, 45, 59, 76, and 119 days after emergence.

FINDINGS: Soil NO_3-N levels were significantly less in the zone of fertilizer application of inhibitor treated plots one week after fertilizer application (during early vegetative growth) than in plots without inhibitors. At 32 days after N application both inhibitors maintained significantly higher ammonium N than plots without inhibitors. At 43 days the effect of the CaC_2 inhibitor on soil ammonium-N was not measurable in the zone of fertilizer application. At 43 days DCD was still maintaining approximately 65% of the ammonium N for either CaC_2 treated plots or plots without inhibitor. The percentage of plant N derived from fertilizer (PNDF) and the percent of fertilizer N recovered (PFNR) by the crop were significantly higher for the banded urea treatments at the V7 stage (30 days after emergence). At 76 days after emergence significantly greater PNDF and PFNR were found in plants harvested in the nitrification inhibitor treatments as compared to the banded urea and large urea pellet treatments. This information

suggests that the low amounts of NO_3-N found early in the inhibitor treated fertilized plots is correlated to the low amounts of N uptake also found in those plots early in the season. A greater accumulation of N found in the inhibitor treated plots late in the season follows the higher amounts of NO_3-N found later in the Inhibitor treated plots. These data demonstrate the importance of timing the release of inorganic N (particularly NO_3-N) by the inhibitor treated fertilizer to the period of maximum crop N uptake.
Data collected in 1991 showed similar relationships with respect to N uptake and nitrification inhibition. In 1991 we measured an 8 bushel increase in plots fertilized with the large urea tablets as compared with plots fertilized with conventionally banded urea, and/or inhibitor treated fertilized plots. In 1991 fertilization was done later at V3 verses V1 in 1990. It is possible that the V3 stage was just late enough to reduce inorganic N levels in the inhibitor treated soils to have missed the maximum N uptake period of the crop. Whereas the larger tablets may have dissolved, hydrolysed and nitrified just slow enough to have resulted in greater amounts of inorganic N as compared to the other treatments during the high N demand period of the crop.

INTERPRETATION: The DCD which was intimately incorporated with the urea maintained fertilizer ammonium N in the ammonium form for a longer period of time than CaC_2. The CaC_2 was not as intimately mixed with the urea as the DCD and only placed with the urea in the fertilized Zone. The greater encapsulation found with the DCD may partially explain the increased time of effectiveness measured with the DCD plots. Preliminary experiments in the laboratory with the wax coated CaC_2, indicated that we could expect a total conversion of the CaC_2, to acetylene (acetylene is the actual active agent that inhibits the conversion of ammonium to nitrate) in about 10 days. It is possible that a formation of acetylene gas (acetylene forms when CaC_2 combines with H_2O vapor in the soil atmosphere).
Since we haven't yet analyzed all of the 1992 data so we can't indicate which combination of fertilizer and inhibitor is better at improving fertilizer use efficiency. It is possible that the DCD treatments inhibit the conversion of ammonium to nitrate for longer than required for maximum fertilizer uptake. From the literature we know that rapidly growing corn plants that are past the seedling stage prefer nitrate-N over ammonium-N. We also know that high concentrations of ammonium are toxic to plant roots. It is possible that the duration of delay in the conversion of ammonium to nitrate with DCD may be too long and may actually decrease the total fertilizer N recovered.

FUTURE PLANS: The experiment will be continued for a fourth season (1993) with basically the same measurements taken as in 1991. At the end of the 1993 season we should have enough data to wrap up the experiment. We hope to have all of the ^{15}N-labeled plant material and soil inorganic N data analyzed for the 1992 season by the end of March of 1993.

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

Publications

Anderson, R.L. 1992. Effect of duration of jointed goatgrass interference on winter wheat grain yield. West. Soc. Weed Sci. Res. Rep. Chap. VI: p. 1-2.

Anderson, R.L. 1992. Jointed goatgrass ecology: implications for control. Pages. 2-3 in Wheat Technology Conference: Jointed Goatgrass: Origins - Ecology - Control, Symposium Proceedings. Univ. Neb. 13 pp.

Anderson, R. L. 1992. Jointed goatgrass (Aegilops cylindrica) development and interference in winter wheat. Weed Sci. Soc. Am. Proc. p. 86.

Armstrong, J.S., C.B. Walker, F.B. Peairs and J.F. Shanahan. 1992. The effect of planting date on Russian wheat aphid infestations in winter wheat in Colorado. Annual report to the Colorado State University Experiment Station and Department of Entomology.

Armstrong, J.S. C.B. Walker, and F.B. Peairs. 1992. Assessment of the economic injury level for Russian wheat aphids (*Diuraphis noxia*) Mordvilko. Annual Report to the Colorado State University Experiment Station and Department of Entomology.

Bowman, R.A., and D.J. Savory. 1992. Phosphorus distribution in calcareous soil profiles of the Central Plains. Soil Sci. Soc. Am. J. 56:423-426.

Bowman, R.A., M.F. Vigil, and A.D. Halvorson. 1992. Tillage and cropping influence on soil organic matter pools. Agron. Abstracts 84:319.

Bridges, D.C. and R.L. Anderson. 1992. Crop losses due to weeds in the United States: by State. Pages 1-59. in D.C. Bridges, (ed.) Crop Losses Due to Weeds in the United States. Weed Sci. Soc. Am. Monograph. 389 pp.

Bridges, D.C. and R.L. Anderson. 1992. Crop losses due to weeds in the United States: by crop and region. Pages 60-73. in D.C. Bridges, (ed.) Crop Losses Due to Weeds in the United States. Weed Sci. Soc. Am. Monograph. 389 pp.

Eckhoff, J.L.A., J.W. Bergman, M.J. Weiss, and A.D. Halvorson. 1992. Seed spacing for nonthinned sugarbeet production. Montana AgResearch 9(1):6-9.

Elliot, E.T., D.J. Lyons, A.D. Halvorson, I.C. Burke, C.V. Cole, and C.A. Monz. 1992. Terrestrial carbon pools and dynamics: 1. The Great Plains. Agron. Abstracts 84:255.

Fixen, P.E. and A.D. Halvorson. 1992. Land tenure effects on phosphorus management. p. 106-110. In J.L. Havlin (ed.), Proceedings of the Great Plains Soil Fertility Conference, Vol. 4, March 3-4, 1992. Kansas State University, Manhattan, KS.

Follett, R.H., R.F. Follett, and A.D. Halvorson. 1992. Use of a chlorophyll meter to evaluate the nitrogen status of dryland winter wheat. Commun. Soil Sci. Plant Anal. 23(7&8): 687-697.

Francis, D.D., J.S. Schepers, and M.F. Vigil. 1992. Assessing crop nitrogen needs with chlorophyll meters. In Proceedings North Central Extension-Industry Soil Fertility Conference. November 1992, St. Louis, Missouri.

Gardner, B.R., D.C. Nielsen, and C.C. Shock. 1992. Infrared thermometry and the Crop Water Stress Index. I. History, theory, and baselines. J. Prod. Agric. 5:462-466.

Gardner, B.R., D.C. Nielsen, and C.C. Shock. 1992. Infrared thermometry and the Crop Water Stress Index. II. Sampling procedures and interpretation. J. Prod. Agric. 5:466-475.

Halvorson, A.D. 1992. Management for residual fertilizer phosphorus in soils. In F.J. Sikora (ed), Future Directions for Agricultural Phosphorus Research. Tennessee Valley Authority, Muscle Shoals, AL. TVA Technical Bul. Y-224. p. 116-120.

Halvorson, A.D. and J.L. Havlin. 1992. No-till winter wheat response to phosphorus placement and rate. Soil Sci. Soc. Am. J. 56:1635-1639.

Halvorson, A.D. and J.L. Havlin. 1992. Response of dryland winter wheat to residual P. In J.L. Havlin (ed.), Proceedings Great Plains Soil Fertility Conference, 4:201-206. Kansas State University, Manhattan.

Halvorson, A.D. and J.L. Havlin. 1992. Dryland winter wheat response to residual fertilizer phosphorus. Agron. Abstracts 84:357.

Hinkle, S. E. 1992. Wheel ridges - concepts, construction, yields. ASAE Paper No. 921593, Nashville TN.

Hinkle, S. E. 1992. Speedometer setup for accurate chemical application. Colorado Conservation Tillage Association News, Vol. 4(4):5-6.

Hinkle, S. E., and D. C. Nielsen. 1992. Potential measurement errors with teflon-covered thermocouples. Agron. Abst. 84:17.

Hutchinson, G.L., W.E. Beard, M.F. Vigil, and A.D. Halvorson. 1992. NO and N_2O emissions from perennial grass and winter wheat in the semiarid Great Plains. Agron. Abstracts 84:260.

Kranz, W. L., S. E. Hinkle, and D. G. Watts. 1992. Corn growth stage as a function of various growing degree and ET parameters. Agron. Abst. 84:150.

Peterson, G.A., D.G. Westfall and A.D. Halvorson. 1992. Economics of dryland crop rotations for efficient water and N use. In J.L. Havlin (ed.), Proceedings Great Plains Soil Fertility Conference. 4:47-53. Kansas State University, Manhattan.

Nielsen, D.C., and A.D. Halvorson. 1992. Nitrogen makes winter wheat big - and thirsty. Colorado Rancher and Farmer 46(7):30.

Nielsen, D. C., and S. E. Hinkle. 1992. Field evaluation of corn crop coefficients based on growing degree days or growth stage. Agron. Abst. 84:20.

Schepers, J.S., D.D. Francis, M.F. Vigil, and F.E. Below. 1992. Comparisons of corn leaf N concentration and chlorophyll meter readings. Communications in Soil Sci. and Plant Anal. 23(17-20),2173-2187.

Schuman, G.E., R.A. Bowman, and J.S. Reeder. 1992. Short-term edaphic response of marginal cropland to a reestablished grass community. Agron. Abstracts 84:291.

Shaffer, M.J., F.J. Pierce, A.D. Halvorson, B.K. Wylie, and R.F. Follett. 1992. Nitrate Leaching and Economic Analysis Package (NLEAP) Model. In Proceedings of 22nd Annual Workshop on Crop Simulation.

Tanaka, D.L., and R.L. Anderson. 1992. Fallow method affects downy brome population in winter wheat. J. Prod. Agric. 5:117-119.

Vigil, M.F., J.F. Power, J.S. Schepers, D.D. Francis, and A. Mosier. 1992. Nitrogen recovery of irrigated corn fertilized with large urea pellets placed with nitrification inhibitors. Agron. Abstracts 84:360.

Vigil, M.F., J.C. Yeomans, R.E. Lamond, and A.J. Schlegel. 1992. An overview of nitrification inhibitors and slow release fertilizers. In J.L. Havlin (ed.), Proceedings Great Plains Soil Fertility Conference. 4:77-83 KS State Univ., Manhattan.

GREAT PLAINS SYSTEMS RESEARCH UNIT

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MISSION STATEMENT

Provide leadership in synthesis, quantification, evaluation, and enhancement of knowledge to support the development of sustainable and adaptive agricultural production systems that are biologically efficient, environmentally sound, and economically feasible. Areas of concentration include:

(1) Production, water quality, and environmental change.

(2) Evaluation of existing management practices on a long-term basis, and developing ideas for new management practices.

(3) Use of models for regional analysis.

(4) Creation of decision support systems for on-farm management.

ANALYSIS OF GREAT PLAINS CROPPING SYSTEMS

C. Vernon Cole
Great Plains Sytems Research Unit

CRIS: 5402-61660-003-00D
5402-11000-002-00D

PROBLEM: The semiarid North American Great Plains have been the site of a major disturbance over the past 100 years by conversion of large areas of grasslands to cultivated cropland. This con-version, which in other semiarid areas of the world has led to desertification and drastic losses in productivity, has taken a different direction in North America with the introduction of improved management practices involving minimum soil disturbance, maintenance of residue cover, and higher yielding crop varieties. Productivity of the region is substantially higher now than when sod was broken and shows signs of continued improvement. Soil organic matter levels and nutrient reserves which showed sharp declines in early years have stabilized and are improving under current management. Why are the trends observed in the Great Plains different than in other parts of the world? What mechanisms are responsible for these differences? Can semiarid agroecosystems of the Great Plains be managed for productive and sustainable agriculture given the variable nature of weather patterns and intensive land use?

APPROACH: We have developed an approach to agroecosystem analysis that integrates a complex array of information from laboratory, site, landscape, and regional scales. Process-level information is integrated and used to develop the agroecosystem model or modify existing models. The model is validated using information from regional site networks. Sets of driving variables generated from geographic information and organized with geographic information systems (GIS) are used as model input. Model output is assigned to corresponding sub-regions using GIS to obtain regional information (predictions). Gaps in our ability to explain regional patterns drive new research on processes.

FINDINGS AND INTERPRETATIONS: Simulation analyses of alternative crop management systems for the semi-arid Great Plains were carried out using the Century Agroecosystem model. We analyzed the potential long-term impacts on soil organic matter of more intensive wheat-corn-fallow and wheat-corn-millet-fallow crop rotations using no-till management, and of replanting grass as in the conservation reserve program under historical weather and under projected increased levels of CO_2 and temperature. Simulation of the effects of climate change and elevated CO_2 demonstrated the importance of the direct effects of CO_2 on crop growth. Wheat production is predicted to increase with elevated CO_2, while production of corn, sorghum and millet may decline due to lower summer rainfall in the climate change scenarios. Soil organic carbon was predicted to be increased by climate change and/or elevated CO_2 in all systems in which wheat is grown. A series of publications documenting model development and these analyses is in preparation.

The analysis of historical climate and wheat yields in Colorado was reworked to use actual climatic data rather than the Thornthwaite evapotranspiration model. This improved the quality of the predic-tions and made them independent of inherent assumptions in ET models. The analysis was also modified to identify critical periods in the weather pattern. The procedures were adapted to accept daily hydro-climatic data for 1036 NOAA climatological stations from all parts of the contiguous U.S. The present analysis covers 74 percent of the non-irrigated wheat acreage of Colorado with the potential for 93 percent coverage. The methodology can now be applied to the remaining Great Plains states.

DEVELOPMENT AND TESTING OF MODELS AND DATABASES TO HELP PROVIDE SUSTAINABLE AGRICULTURAL PRODUCTION SYSTEMS

M.J. Shaffer
Great Plains Systems Research Unit

CRIS: 5402-61660-003-00D

PROBLEM: Given the current state of the national farm economy and the renewed concerns about groundwater pollution from nitrates and pesticides, there is an urgent need to find ways to optimize on-farm productions for profit and yet minimize adverse environmental impacts. Time is a critical factor in the overall problem, and we cannot afford 10 or 20 years of additional field research before optimal systems are identified. In addition, while existing data sets provide long and short term information at selected sites, they do not begin to cover the range of soil, climate, and management combinations which are encountered in the field. Farm and natural resource managers lack suitable tools which can provide answers now before additional damage is done to the farm economy and the nation's soil and groundwater resources.

APPROACH: To help solve these problems, models suitable for development and analysis of total crop production systems are urgently needed for use in agriculture. These models should integrate (1) the biological, chemical, and physical factors, (2) cultivars and management practices, and (3) physiological responses of crops to their environment into simulations of total agricultural systems for determining the limits and sustainability of agricultural production in semiarid agroecosystems of the Great Plains and elsewhere in the United States and the World.

FINDINGS: Local climate/weather conditions can have profound effects on soil fertility management and leaching of nitrates. The application of simulation models together with appropriate climate and soil databases provide a mechanism to evaluate current and alternative management options and identify techniques that maintain or improve soil fertility while minimizing nitrate leaching. The NLEAP model and databases were applied in the form of sensitivity analyses to rainfed climate conditions found in the midwest and to irrigated agriculture in the semiarid Great Plains. Model results supported with field data were used to illustrate the importance of local climate/weather patterns on soil fertility management and annual nitrate leaching amounts and distributions. Site-specific management strategies appear to be necessary for optimal fertility management and control of nitrate leaching. Real-time management decisions at each site can provide additional fertility and leaching benefits.

The NLEAP Soil and Climate databases continued to be developed, tested and published. The Upper Midwest Soil Database, published 1991, was updated with a new equation for cation exchange capacity (CEC) provided by the SCS, and all other Soil databases were redone to include the equation change. Other products included a raster map of soil survey areas of the U.S (provided by SCS) and a map of climate stations with evaporation measurements for the U.S. (developed by ARS). Several regression relationships to predict evaporation, especially in winter, were developed to complete the Northeastern and Southern Climate

databases. The primary obstacle to be overcome for completion of the Western Climate is the generation of monthly evaporation during winter. Therefore, the West may be further divided into subregions where states with the most complete datasets can be released in NLEAP format first.

Products of this research in 1992 included release of the Upper Midwest NLEAP Database Version 1.2 through ARS and publication of the Northeast Database Version 1.2 and Southern Database Version 1.2 through the Soil Science Society of America. The Western Soils Database Version 1.2 is completed and will continue to be tested as western climate databases become available.

The nutrient submodel component of the RZWQM model was refined to include greenhouse gases and tested against field data from the Netherlands and Columbia, MO. Technical documentation was prepared and published that describes the theoretical basis of the nutrient and soil chemistry components of RZWQM. Material for a book chapter that includes summaries and testing of the NLEAP and RZWQM nutrient submodels was developed in cooperation with Soren Hansen from Copenhagen, Denmark. The submodels will be tested further in conjunction with the rest of RZWQM as applied to field scale research plots in the Midwest, Colorado, and elsewhere. Considerable interest in RZQWM with respect to nutrient and pesticide movement continues to be shown locally by irrigation districts and nationally by the MSEA people. Additional model testing and validation studies were continued in cooperation with Soren Hansen, L. Ahuja, J. Hanson, G.R. Dutt (Univ. of Arizona), and K. Rojas.

The GPAP decision support system for the Great Plains was initiated with design of the overall system structure. The model will be developed using a combined X-windows/MS windows approach suitable for use on both DOS-PC and UNIX based systems. A demonstration prototype is under development based on the NLEAP and FLEXCROP models. This will provide a demonstration and development platform for the primary GPAP modeling work.

INTERPRETATION: Continued development of these models and databases provide tools urgently needed by farmers, action agencies (SCS, EPA, extension, State agencies), consultants, water districts, university and ARS researchers, and others.

FUTURE PLANS: NLEAP database development will continue for the western region of the U.S. The NLEAP model will be field tested against plot data from Colorado, Iowa, Nebraska, South Dakota, and elsewhere. Regional testing of the model will be done in Colorado and Iowa in cooperation with work under a related CRIS project. Development and testing of the RZWQM model will continue for decay of crop residues and manure, field testing of the model, and addition of a soil gas exchange and reaction submodel. The demonstration prototype for the GPAP project will be completed and development will continue on the framework for the primary model.

SUSTAINABLE AGRICULTURAL PRODUCTION SYSTEMS FOR THE GREAT PLAINS

Gregory S. McMaster
Great Plains Systems Research Unit

CRIS: 5402-61660-003-00D
5402-13610-003-00D

PROBLEM: Agricultural systems today must confront critical issues such as sustainability, productivity, environmental impacts, and possible global climate change. Addressing these issues is complicated by spatial and temporal variation in climate, soils, germplasm, and management practices. Given that so many processes are involved ranging across many disciplines, how can we best proceed with addressing these issues?

APPROACH: In selecting different cropping systems, it is necessary to understand the developmental and physiological responses of different crops and varieties to fundamental environmental factors. Management practices can then be evaluated by how they affect fundamental environmental factors. In the last decade, a great deal of research was conducted towards understanding the development and physiology of small-grain cereals and other crops for specific environmental variables. Very little is known about how management practices affect crop development and physiology. Since it is impossible to study all possible management practices for all combinations of soils, climates, and crops, a combination of experimentation and simulation modeling is being used to synthesize existing knowledge and fill knowledge gaps on crop responses to the environment and management. The approach is first to try to quantify the effects of management practices on the physical environment (e.g., soil temperature, soil water, soil nutrients). Then, integrate the existing knowledge of how the physical environment affects crop development and physiology, combined with experimentation to fill knowledge gaps, into detailed mechanistic models that simulate the processes. Implicit with this approach is the assumption that realistic, detailed processes must be simulated in the models.

This approach has several advantages. (1) Alternative management practices can be evaluated by determining their impact on the physical environment, then using simulation models to assess system response to the altered physical environment under different climates and soils. This significantly reduces the time and resources necessary to conduct extensive field studies for different management practices, soils, and climates. (2) The suggested responses inferred from the models can then be validated by selective field experiments, thereby shortening the time and resources necessary to develop and evaluate different cropping systems. (3) Future management practices can be evaluated as they emerge using the approach outlined above, once again shortening the initial evaluation period. (4) The models can also be used to evaluate altered simulated physical environmental conditions. If certain alterations of the physical environment seem particularly advantageous, then this suggests areas that management practices should focus on to produce the desired affect. New management practices may need to be developed. (5) If the models reasonably simulate responses to the physical environment, and if all the important developmental and physiological processes are simulated, then other issues such as global change

impacts can be evaluated. It is important that all the potential developmental and physiological processes are simulated in order to have confidence in the predictions of the model, and most importantly, so that an understanding of why the system has responded as it did. Too often current simulation models have been used to assess global change where a number of important developmental and physiological processes have not been included in the model (or they have incorrectly been included), and no understanding of the system response has been gained.

PROGRESS: Within the context of the above approach, specific projects have been, and are being, initiated to understand crop response to management practices and the environment. Some of these are listed below.

(A) Wheat yield and yield component responses to different rotations and soils across an ET gradient have been examined for three years. Collaborators include Drs. Jack Morgan, Gary Peterson, and Dwayne Westfall. Findings to date indicate that the primary yield component controlling the yield response of wheat in these systems is spike number determined by tiller abortion rates. Those environments resulting in slightly higher water levels result in significantly lower tiller abortion rates, resulting in higher yields. These findings corroborate those of Project B.

(B) Water is the main limiting resource in the Great Plains, yet little work has examined water stress effects on wheat development and physiology in the field. An irrigation scheduling study was conducted in collaboration with Drs. Wally Wilhelm and Jack Morgan to address this knowledge gap. The first manuscript being submitted reports that the optimal time to irrigate is at jointing because tiller abortion rates are reduced, resulting in increasing the main yield component of spike number. This experiment corroborates the findings of Project A.

(C) The effects of tillage and residue cover on wheat development and physiology are being studied in a long-term experiment currently underway at the Colorado State University Horticulture Farm. Companion studies are being conducted in Michigan and Ontario, Canada. Collaborators include Drs. Fran Pierce, Marie-Claude Fortin, Laj Ahuja, Carlos Alonso, Marvin Shaffer, Gale Dunn, and Rob Aiken. One preliminary finding has been that tillage practice is critical in determining seedbed moisture conditions, thus controlling stand establishment.

(D) Atmospheric CO_2 levels have increased in the last 100 years, and are expected to continue to increase substantially in the next several decades. It is unclear how higher atmospheric CO_2 levels will affect crop development and physiology. A growth chamber experiment has been conducted looking at whole plant wheat development and growth responses to ambient and elevated CO_2 levels. Some of the findings related to wheat development are that CO_2 does not effect phenology, but increases the rate of leaf appearance which has many ramifications on canopy development such as the rate of tiller appearance.

(E) Integration of developmental and physiological processes into detailed mechanistic simulation models has been accomplished by developing two models for winter wheat (SHOOTGRO and SPIKEGRO). The initial objectives of these models have been completed and published. The next iteration of improvements are being conducted, with two major areas of effort. (1) The models are being converted

to simulate spring wheat and spring barley. Collaborators include Drs. Wally Wilhelm, Al Black, Al Frank, Armand Bauer, Steve Simmons, and Howard Skinner. (2) Plant responses to changes in the soil environment resulting from management practices are being incorporated.

These models are being used to integrate knowledge on various physiological and developmental processes, thereby identifying major knowledge gaps. The purpose is to evaluate the effect of climate, germplasm, and management practices on small-grain cereals.

FUTURE PLANS: The preceding projects will be completed, continued, or initiated as appropriate to the project objectives. Several projects will receive priority this coming year:

(1) Converting SHOOTGRO and SPIKEGRO from winter wheat to spring wheat and spring barley (see Project E above).

(2) Combining the SHOOTGRO and RZWQM models.

(3) Working with South African scientists to modify SHOOTGRO so that irrigation/water stress effects are better simulated.

(4) Continuing the soil management effects project on wheat development and physiology (see Projects A, B, and C above).

(5) Continuing the cropping systems experiment for different rotations and soils across an ET gradient (see Project A above).

(6) Soil management effects on corn development and physiology will studied in addition to the wheat work already underway (see Project C above). This will be a collaborative project among other scientists in my Research Unit as well as other ARS and CSU scientists.

ECOLOGY AND MANAGEMENT FOR SUSTAINED RANGELAND PRODUCTION IN THE GREAT PLAINS

J.D. Hanson and B.B. Baker

CRIS: 5402-11660-001-00D

PROBLEM: The goal of this project is to provide an operational framework for Great Plains database generation, accumulation, integration, and management from which alternative agricultural strategies can be developed and tested for economic, environmental, and social impacts. The ultimate charge is to develop products that implement the concepts of the systems approach to address the problems of Great Plains agriculture. The problem (with emphasis on rangeland) can be discussed in three components: model development and validation, remote sensing, and ecological research. Our research involves the maximization of rangeland and cropland use while preserving the natural resource. In this vein, comprehensive plant growth simulation models are being developing. Remote sensing techniques are also being used to estimate rate processes such as evapotranspiration and primary production. These techniques can also be used to index variables such as cover and green leaf area. The information provided by remote sensing techniques can be used to parameterize models and verify their predictions. The combination of spatial information and modelling will maximize the usefulness of both tools and facilitate extrapolation of simulation results to large areas such as farms, ranches, and entire regions. The ultimate goal is to develop and validate process-oriented models that can accept spatial information, along with necessary in situ data, as input. A delicate balance between water, temperature, and productivity exists in the semiarid rangeland. In these rangelands, the "ecological health" or sustainability of the system is largely determined by the activity occurring within the rooting zone. In the short term, decomposition of soil organic matter apparently enhances production. However, in the long term, soil organic matter depletion leads to a degradation of the ecosystem.

Specific Objectives During 1992

1. Complete the development and release of SPUR2.

2. Use SPUR2 to simulate various sites within the United States and other countries (Argentina, South America)

3. Evaluate the effect of long-term stocking rate and grazing system on soil organic matter.

4. Compare multitemporal and unitemporal classification accuracy using Landsat TM imagery.

5. Determine the variability of soil parameters at various landscape positions in northeastern Colorado.

APPROACH: We are using a systems approach to solve questions describing rangeland dynamics. This research will extend our capability and leadership in identifying land cover type and will aid in determining the general health and

vigor of rangeland production systems. We will also develop methods for monitoring grasslands and evaluating the influence of human-induced environmental and climatic change and provide knowledge on the effect of potential climate changes on grassland and livestock production. Remote sensing research and field research were used to attain our objectives.

FINDINGS AND INTERPRETATIONS: The SPUR2 model was released and is currently being validated for sites in western South Dakota and Argentina, South America. The user interface was completed and known problems in the model were corrected. Soil and plant data bases were expanded. The model was presented to personnel concerned A stand-alone plant establishment model was developed and extended to work with dry beans and winter wheat.

A land cover classification of a 24,732 acre test area in Weld County, Colorado, was completed using six data sets containing Landsat TM data obtained in May, July, and September, 1991. Four data sets were composed of TM spectral bands in multitemporal and unitemporal date combinations. Two data sets were multitemporal combinations of NDVI and Tasseled Cap spectral transformations. The multitemporal and unitemporal data sets were evaluated using combinations of one, tow, and three dates. When 12 information classes were considered (using test polygons for accuracy assessment), the Tasseled Cap transformation and the 15 TM spectral band data set had the highest overall classification accuracy (90%). NDVI classification ranked second and the July-September 10 TM spectral band data set ranked last. The overall classification accuracy of the TM spectral 6-band July data set was 75%. The spring-summer-fall multitemporal image data reflects the phenology of vegetation. Examination of the spectral information contained in the land cover class spectral statistics suggests a "characteristic shape" when the DN cluster mean values for TM bands 5, 4, and 3 were plotted against date (May-July-September). This "DN-month" shape approximated the phenology of the vegetation and provided an effective tool for separation nd identification of land-cover classes.

Three range sites located at the Central Plains Experimental Range were selected to investigate variability within soil parameters. The sites included a north-facing slope, a south-facing slope, and a playa. Sampling was done on a grid at each site. Bulk density, soil texture, moisture desporption, and root biomass samples were taken with a 7.6 cm gidings soil exploration probe. Cores for determining soil carbon and nitrogen were extracted using a 3.8 cm probe. Plant cover and species identification was performed by visual analysis and interpretation inside a standard sampling quadrat. Production of grass, shrub, forb, and cactus was determined by clipping, separating, drying, and weighing the vegetation within the quadrat. Bulk density, texture, plant analysis, carbon, and nitrogen determinations are complete. Some trends are visible within the data. Slope positions are generally more sandy as compared to more clayey soils in the playa. Correlations between vegetation and certain soil parameters should be evident when the study is complete and the degree of spatial variability determined.

FUTURE PLANS: Future studies will combine SPUR2 simulation and LANDSAT imagery for regional green biomass assessment. The technique should incorporate the best attributes of both tools. The following approach is one method that could be used to combine the two tools. LANDSAT imagery should be acquired at key periods

throughout the growing season. The LANDSAT data could then be used to stratify the region into greenness strata. Meteorological sites capable of providing historical climatic information necessary to drive SPUR must then be located and climatic data obtained. SPUR simulation sites should be placed in as many different greenness strata as exist around each meteorological site. Soils occurring at each simulation site must be identified and hydrology and soil parameters determined from soil data-base information or soil samples. Historical grazing information must also be acquired for simulation sites that are grazed by livestock. Model warm-up should be accomplished by running the model for at least 18 to 20 years prior to the study period using historical climatic data and grazing information. SPUR predictions of green biomass and the corresponding average vegetation index value within each strata should be used to develop a calibration curve which relates green biomass estimates to vegetation index response. The calibration model and the average vegetation index values for each greenness strata could than be used to estimate green biomass amounts for all strata occurring within the region.

The success of SPUR simulation of green biomass production is dependent on proper parameterization of the model. The collection of soil samples, from which hydrology component parameters can be estimated, may improve the ability of the model to predict green biomass amounts at that location. Determining how best to initialize the model remains a problem. One approach to model initialization would be the collection of baseline information on the distribution of carbon and nitrogen in the various biotic and abiotic components of the ecosystem, however, it would be impractical to assume that enough information could be collected to characterize multiple sites. Running the model for 18 to 20 years prior to the study period appears to be necessary for model warm-up. A cooperative arrangement is being planned with personnel from Texas A&M University to combine the work they have on the SPUR hydrology component with our improvements for SPUR2. Concomitantly, in the cooperative work will lead to the development of a validated nitrogen fixation module that will be tested on honey mesquite.

Our inability to adequately characterize the complex spatial interactions that affect biomass production and utilization suggest that SPUR2 should be run on an individual site within a grazing unit rather then attempting to simultaneously simulate multiple sites. Prediction errors will result from the lack of spatial connectivity, however, the errors will not be compounded by incorporating guesses of the sites preference and site limitation vectors for grazing distribution, as was the case in the current study.

Future studies designed to develop relationships between sample estimates of dried green biomass and LANDSAT derived vegetation indices should combine the data into areas of similar biological response. Strata can be developed by delineating various plant communities or by classifying a LANDSAT image into areas of similar spectral response. By stratifying the area, fewer samples are required to characterize each region. In addition, the averaging of multiple samples within each strata will reduce the affect of errors associated with sample point location and changes in soil brightness. The design of a stratified sampling scheme coupled with the use of global positioning devices should improve the distribution and location of sample points within the each strata.

THE ROOT ZONE WATER QUALITY MODEL (RZWQM) VALIDATION AND ENHANCEMENTS

RZWQM Team: K.W. Rojas, M.J. Shaffer, J.D. Hanson, C.V. Alonso, R.M. Aiken, G. McMaster, L.R. Ahuja, Q. Ma, and V.A. Ferreira

CRIS: 5402-13660-002-00D

PROBLEM: One important goal of ARS is to develop techniques and knowledge that help minimize the effects of agrichemicals on surface and groundwater quality, and maximize their efficiency for crop production. Recent research has shown that the management practices associated with agriculture, such as tillage system, crop residues, methods and timing of fertilizer, pesticide and water applications, surface shaping, and plant shoot and root architecture, have a very significant impact on hydrologic and chemical response. The process-based models that synthesize and quantify the limited experimental information can then be used to analyze the effects of different management schemes for varying soil and climate conditions. The RZWQM has been and is being further developed with this purpose in mind. Other comparable models generally do not include such comprehensive effects of management. The RZWQM is a comprehensive, generally modular, integrated system model of the soil-water-plant-atmosphere-management system. It has six main components in Physical Processes (water, chemical, and heat transport; ET), Plant Growth, Nutrients, Pesticides, Soil Chemistry, and Management. This simulation core is complemented by friendly user interfaces for input and output. The input is built around menu-driven entry screens with facilities for on-line help and determination of default data/parameter values. The output interface provides publication-quality graphs and tabular output, for quick interpretation of results.

Specific Objectives During 1992

1. Validate different model components against data, and make refinements where necessary.
2. Enhance the model by adding certain important new features.

APPROACH: Two experimental data sets were available for validation: (1) data on movement of water, Br tracer, and two pesticides, cyanazine and metribuzine; in bare field plots from Wageningen, The Netherlands; and (2) data on surface runoff and movement in soil of water, atrazine, and cyanazine in a small watershed near Watkinsville, GA, for three years. For The Netherlands site, the soil hydraulic properties were estimated from soil texture, bulk density, and 1/8 bar water content. The pesticide degradation equilibrium adsorption-desorption properties, and kinetic adsorption-desorption parameters were available. For the Georgia site, the soil hydraulic properties were estimated from soil texture and bulk density, and the pesticide parameters from the ARS pesticide database. Furthermore, a surface crust had to be imposed at the Watkinsville site to match measured and simulated runoff amounts. The rainfall and weather inputs were mostly available for both sites.

FINDINGS AND INTERPRETATIONS: The soil hydraulic properties were estimated from approximate techniques, the RZWQM gave good predictions of soil water content distributions with depth at a number of times for each site. At The Netherlands site, the simulated pesticide distributions were also generally good, except for some discrepancy for the last time (120 days after application). For the Georgia site, the pesticide movement in soil as well as the concentrations of pesticide in runoff water were predicted reasonably well.

The RZWQM has been enhanced by adding/improving the following components: (1) redistribution of water during Green-Ampt infiltration below the wetting front; (2) manure application; (3) decomposition of crop residues at the soil surface; and (4) change in half life of a pesticide in later stages. Addition of a freezing-thawing and snow accumulation-melt component to the heat transport and ET models is in progress. The ET component is also being expanded in the process.

FUTURE PLANS: In the years ahead, the model will receive extensive testing as a complete system. This will be accomplished by working with the Management Sytems Evaluation Areas (MSEA's) of the Presidents Water Quality initiative. Extensive databases are being collected that will help in model validation. The model will also help the MSEA's explain and evaluate their data and extrapolate results regionally. We also plan to continue working with several other groups which are colaborators in using the model both locally, nationally, and internationally. We plan to work with SCS-TISD in Fort Collins and some other SCS locations.

APPLICATION OF THE NLEAP MODEL TO REGIONAL NITRATE LEACHING ALONG THE SOUTH PLATTE RIVER IN EASTERN COLORADO

M.J. Shaffer and B.K. Wylie
Great Plains Systems Research Unit

CRIS: 0500-00002-006-00D

PROBLEM: Groundwater is the primary source of supply in the United States for rural inhabitants, small and large communities, irrigated and rangeland agriculture, and industries that do not have access to adequate supplies of surface water. Problems with high NO_3-N levels in groundwater have been tied to agricultural practices and are well documented in the midwestern corn belt, the southeastern coastal plains, karst regions, and irrigated areas in the western U.S. Many research programs designed to address this problem have relied heavily on data obtained from isolated research plots with little consideration given to NO_3-N leached across the region. Producers, regulators, Extension, and SCS are interested in knowing the specific locations of the regional hot spots and the relative contributions of various potential sources of nitrogen that may have contributed to these problem areas. These groups also want to know which alternative management practices offer the most effective means of reducing the risk of NO_3-N leaching.

APPROACH: The NLEAP model is being used in conjunction with GIS technology to investigate regional distributions of NO_3-N leaching while seeking alternative management solutions that make sense across broad geographical areas. Regional groundwater NO_3-N data from 317 wells are available across the shallow alluvial aquifer along the South Platte River near Greeley. This information is being used to test NLEAP NO_3-N leaching indices and determine if a correlation exists between the patterns of simulated regional indices and the observed patterns seen in groundwater NO_3-N concentrations.

FINDINGS: The feasibility and applicability of a regional NLEAP application within a GIS framework was demonstrated across a 642 km^2 area in eastern Colorado. The conclusion was made that the NLEAP model is capable of identifying regional NO_3-N leaching distributions by using the NO_3-N leached (NL) index after a single year of simulation for commercial fertilizers or at steady state for a mix of commercial fertilizers and manures. Correlations between NLEAP projected nitrate leached (NL) and 1989-1991 observed groundwater NO_3-N concentrations were higher under steady state conditions than when using one year simulations.

The Landsat TM image in conjunction with ground truthing was also used to identify feedlots in the study area. GIS buffering was used to identify irrigated agricultural areas with high, moderate, and low probabilities of annual manure applications, i.e. close, moderate, and distant proximity to feedlots. When manure applications were incorporated into the NLEAP spatial distributions, again NL indices were more strongly correlated to 1989-1991 groundwater NO_3-N concentrations when steady state simulations were used as opposed to a single year. The steady state correlation with manure was higher than the correlation

with only commercial fertilizers. Groundwater NO_3-N concentration was best related to the NLEAP NL index when the history and type of management were taken into account.

Collaborative efforts were encouraged though meetings with water conservancy districts, State agencies, CSU extension, SCS, EPA, and producer groups. Intense interest in the project has been shown by local State agencies, SCS, EPA, water districts, farmers, and the local press. Although the purpose of the study was to test NLEAP in a regional setting, the observed groundwater NO_3-N map (1989-1991) as well as the results from the NLEAP model simulations suggested that irrigated agriculture may have played a role in the development of NO_3-N hot spots in the shallow alluvial aquifer near Greeley. The Colorado Rancher and Farmer published an article entitled "Nitrates Can Leach, but They Can't Hide" by Sally Schuff in their November, 1992 issue. Several newspaper articles on the topic also appeared. Scientific details of the NLEAP regional study were prepared as a journal article and submitted to the Journal of Soil and Water Conservation.

Proposals for additional funding were prepared and submitted.

PROPOSALS:

Regional Analysis and Management of Nitrate Leaching Hot Spots Using NLEAP. 12-16-92. M.J. Shaffer, R.M. Waskom, B.K. Wylie, R.A. Schierer, and D. Dubois. submitted to CSRS, Special Research Grants; Water quality: pending

Spatial Distribution of Nitrate Leaching "Hot Spots" and Nitrate Contributions to the South Platte River Basin Aquifers. 1-29-92. Colorado Water Resources Research Institute: (Submitted by CSU) funded.

Farm Management in the Northern Colorado Water Conservancy District: Water Efficiency and Nitrate Leaching. 1-29-92. Colorado Water Resources Research Institute: (Submitted by CSU) not funded.

NLEAP Training and Support:

NLEAP training courses were developed at both the introductory and advanced levels. The target audiences were SCS (from all areas of the nation), Extension, ARS, and University personnel. A two-day introductory course provides users with the mechanics of the model; the basic structure of the model; the nutrient, water, and agricultural systems involved in the nitrate-nitrogen cycle and nitrate-nitrogen management; information on how to get the data required to run the simulation; and details on application and interpretation of the simulation results. The advanced course goes into these subjects in more detail and, in addition, covers the configuration of the model for local conditions, creating/editing local databases, and "advanced" applications of the model.

The NLEAP model was updated to correct and improve portions of the NLEAP program and its operation, and to improve simulation of organic residue mineralization.

INTERPRETATION: The NLEAP model is being established as a tool capable of identifying regional NO_3-N leaching hot spots. The pilot study in eastern Colorado validated the use of the NLEAP NO_3-N leached (NL) index for identifying NO_3-N distributions and hot spots across a shallow regional aquifer under irrigated agriculture.

FUTURE PLANS:

Regional Application of NLEAP

Refine and test the use of the NLEAP model leaching indices in the identification of regional distributions of NO_3-N leached from irrigated agriculture. Test the hypothesis that regional leaching of NO_3-N from agriculture occurs in well defined hot spots areas that are a function of soil properties and management history. Determine the extent to which the NLEAP model can be used to test alternative management practices that may reduce NO_3-N leaching from irrigated agriculture. Using the NLEAP model, determine the potential long term regional effects of proposed alternative management practices on groundwater quality along the South Platte River. In conjunction with NLEAP, assess the feasibility of quantitatively separating major agricultural management factors that may be contributing to regional groundwater NO_3-N contamination (manure, commercial fertilizers, irrigation type, and crop type and rotations).
Demonstrate how the NLEAP model and GIS maps can be used to assist and support the SCS, extension, water districts, and consultants in assessing each farmer's current and alternative management options in terms of reduced NO_3-N leaching, and maintenance to crop yields.

GIS-NLEAP interface

Re-work portions of the NLEAP program to allow program expansion. Expansion could include such things as a batch mode for the GIS-NLEAP interface, incorporation of irrigation scheduling into the simulation, and the ability to use the NLEAP interface to create local GIS-NLEAP or NLEAP databases. Develop a software/procedural system to interface GRASS-GIS and NLEAP in order to identify the regional distribution of potential nitrate-nitrogen leaching problems and facilitate the development of solutions to regional nitrate-leaching problems.

NLEAP technology transfer

Work with the SCS to develop a NLEAP support system within the SCS and a NLEAP national training program for SCS personnel who will be responsible for training other SCS personnel and for NLEAP program support within the SCS. Work with the SCS to develop the use of NLEAP as an educational tool in training personnel in the nitrogen, water, and agricultural management systems involved in water quality and developing best management practices for water quality. Work with SCS-TISD to incorporate a version of NLEAP into their Field Office Computer System (FOCS).

ROOT ZONE WATER AND CHEMICAL TRANSPORT AS ALTERED BY MACROPORES

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CRIS: 5402-13660-002-00D

PROBLEM: The work done by soil physicists over the last few decades has greatly enhanced our understanding of the water and chemical transport processes. However, not enough has been done to fully understand and quantify the effect of management practices. Yet, it is only through management practices that we can have some degree of control over these processes. Preferential flow paths and crop rooting patterns are, in a sense, a manifestation of certain management practices.

Major thrust of this work will be to develop basic understanding and theoretical framework for water and chemical transport processes in a field as influenced by soil conditions, such as macropores, and practices such as type of tillage, cropping, surface cover, chemical placement, and surface shaping. Special emphasis will be on the dynamics of a row-crop system of corn or soybeans, planted on lands of varying topography and soil profile characteristics. Effects of rooting systems on decayed root channels, earthworm activity, and spatial non-uniformity of water and chemical transport will be of great interest. The row-crop situations often involve 2-dimensional spatial changes as well as temporal changes in soil properties and surface conditions, and 2- or 3-dimensional water flow and chemical transport pathways. Basic knowledge and theory of processes under these conditions are very limited or essentially lacking at present. This information must be developed if we are to prevent ground and surface water pollution from agricultural chemicals, while maintaining and enhancing crop production.

Specific Objectives During 1992

Analysis of data collected in a series of column studies to quantify the transfer of soil surface-applied chemicals to macropores and their downward transport through the root zone; simulate the observed data using a 1-dimensional model (RZWQM).

APPROACH: The following characteristics were compared between soil columns of differing conditions: depth of wetting front following redistribution, water and chemical (Sr and Br) profiles following redistribution, amount of water in runoff or seepage, amount of chemical in runoff or seepage. The conditions in which the columns differed were initial soil water content, constant head infiltration versus rainfall, surface cover, surface layer of large soil aggregates, no macropores versus a continuous macropore, and multiple macropores. Parameterizing the model used accordingly, the conditions of each column could be simulated, and the results compared to the observed data. The saturated hydraulic conductivity and water characteristic of the soil were measured on separate columns. The unsaturated hydraulic conductivity was calibrated on one set of redistribution data.

FINDINGS AND INTERPRETATION: The analysis of data and interpretation of results are still in progress. The results so far indicate the following: (1) The simulated infiltration and soil water content profiles compared very well with the observed data, provided the hydraulic conductivity used in the Green-Ampt infiltration model was calibrated. This involved reduction in the measured saturated conductivity for the effects of the wetted profile shape, air entrapment, and possible the differences in packing. (2) Without surface aggregates or macropore, the simulated Br movement in soil and the Br transfer to runoff were also close to the observed data, with calibration for the non-uniform mixing factor for the rainfall-soil interaction. (3) The presence of soil aggregates required the introduction of certain microporosity in the surface layer that retarded downward movement of Br in soil and increased its transfer to runoff or micropore flow. (4) The water and chemical flowing out of the macropore at 30 cm depth were simulated well only when the sorptivity of the macropore wall was decreased. This decrease in sorptivity could be ascribed to compaction of soil at the wall created when the hole was formed with a 3-mm rod.

FUTURE PLANS: The results will be used to refine the ARS Root Zone Water Quality Model. Then the model will also be used to quantify and interpret the extensive field data on the transport of nitrate and pesticides to surface and groundwater from MSEA sites in the midwest. Further experiments will be conducted in soil columns in which the plants are grown, to study the macropores generated by decaying roots, and their effect on preferential water and chemical movement.

ROOT ZONE WATER AND CHEMICAL TRANSPORT AS AFFECTED BY MANAGEMENT AND ROOT WATER UPTAKE IN ROW CROPS

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CRIS: 0500-00032-022D

PROBLEM: The work done by soil physicists over the last few decades has deepened our understanding of the basic theory of water and chemical movement in soil. However, not enough has been done to fully understand the effects of soil management on the control of chemical movement through and out of the root zone. The advent of mechanistic, two-dimensional models of soil water, heat and chemical movement now allows in-depth study of management effects on the soil environment in row crops.

The effects of the crop plant on the movement of chemicals have largely been ignored. The major thrust of this work will be to develop an understanding of soil management effects on the soil properties, transport processes, and soil environment and how changes in the soil environment affect the growth of the corn root system. Special emphasis will be placed on how the position of the root system (row vs. interrow) with the concurrent uptake of water and chemical by the plant, affects the potential leaching of common agrichemicals and fertilizers into groundwater supplies.

Specific Objectives During 1992

Develop a two-dimensional corn root growth model for use with finite element soil environment models; Use the model to simulate the effect of two-dimensional water uptake by root systems on subsurface water and chemical movement out of the root zone and into the groundwater.

APPROACH: The model uses two-dimensional temperature, bulk density, and water content distributions predicted by the SWMS_2D model to determine the fitness of different soil zones for root growth. The model then grows roots into the soil based on the soil environment and the phenological development of the plant. The plant root system, in return, affects the soil environment and transport processes through water and chemical uptake by the plant.

FINDINGS AND INTERPRETATIONS: Testing has shown that the model will adequately reproduce root density distributions as found in the literature. Root growth predicted by the model is responsive to changes in the soil environment, especially to bulk density and temperature changes.

Water content distributions show a drier zone directly beneath the plant because of water uptake by the root system. Subsurface water flow paths show water moving from wetter zones that do not contain roots to the drier zone containing roots, as well as differences in vertical water fluxes between the two zones. Mobile chemicals in the water also move towards the root zone and imply that chemical leaching out of the root zone may be modified by the placement of the chemical near the crop plant in the row instead of in the interrow zone.

FUTURE PLANS: We will use the model for the study of soil management effects on root system development, the study of climatic conditions on root water uptake, and the study of root water uptake on subsurface water and chemical transport. We will modify the specifications of boundary conditions in the model to make the current model more responsive to changes of climatic conditions.

The long-term goal of this work is to study the effects of the crop plant and management on chemical leaching into the groundwater. Specific soil and fertilizer management techniques such as band fertilizer placement, ridge-tillage systems, and crop residue management systems will be studied to recommend practices providing the most favorable soil environment for root growth and to minimize chemical movement out of the root zone.

TWO-DIMENSIONAL CHARACTERIZATION OF TRANSPORT IN VARIABLY-SATURATED SOILS

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CRIS: 5402-13660-002-00D

PROBLEM: The long-term goal is the search for improved water management practices that maximize the efficiency of irrigation water, fertilizers, and pesticides, and minimize their leaching through the judicious use of computer simulations and field validations. In recent years comprehensive, one-dimensional models of movement of water, heat and chemicals in the root zone of agricultural fields have been developed. It remains an open question whether these models can handle row-crop situations displaying highly pronounced spatial variations and temporal changes in soil properties, surface conditions, and transport pathways. In order to examine this issue, research models of leaching in the unsaturated zone must be extended to routinely include two-dimensional characterizations.

APPROACH: In support of such characterizations, advanced two-dimensional computer models of soil water, heat, chemical transport (SWMS_2D) and root growth (2DCORN) in the unsaturated zone have been implemented by the authors. These are dynamic, finite-element models designed to evaluate land management practices in situations ranging from row-crop plots to hillslope scales. Two-dimensional models require processing massive amounts of distributed data. Thus, a concomitant need is the availability of better techniques to readily create, manage and display large data files. Consequently, a major effort was put into the development and implementation of advanced graphical user interfaces (2DSHELL, 2DSOILS, and GRAFTOOL) to process multi-dimensional input/output data. Existing models require refinements of boundary conditions and internal sinks. Linking the flow of mass and energy across the boundary exposed to the atmosphere in response to atmospheric conditions will allow the model to simulate changes in chemical movement in response to weather patterns.

Management techniques to be investigated include, but are not limited to, the following: 1. Examine the potential benefits of combined alternate furrow irrigation and banded fertilizer and pesticide application to decrease chemical movement out of the root zone. In particular, determine the combination of water depth and fertilizer position for different soil types that leaves the most fertilizer in the root zone under conditions of excess irrigation; 2. Examine effects of plant water uptake on chemical leaching. Investigate the positioning of fertilizer and pesticides in relation to the plant on uptake by the plant, variations in water flow patterns induced by plant water uptake, and resultant chemical leaching; 3. Examine variations in subsurface water and chemical transport that occurs from the upper end to the lower end of row-cropped, irrigated fields.

FINDINGS: Preliminary simulations of unsaturated flow patterns with alternate furrow irrigation shows a separation of water flow paths between water moving out of the root zone and water remaining within the root zone. These results are

consistent with the findings of Kemper et al. (1975) and Hamlett et al. (1986) which show that placing chemicals under the ridge and in proper relation to the water stage reduces the leaching out of the root zone. We plan to expand this modelling effort to determine the best combination of water depth in the furrow and placement of fertilizer and pesticides in the ridge to minimize chemical leaching from the root zone.

INTERPRETATION: Two-dimensional models are capable of simulating the variable surface configurations exhibited by ridge-tillage of furrow irrigation systems, easily incorporate spatial variability in soil thermal and hydraulic properties and allow the removal of water and chemicals by the root system within the soil profile.

FUTURE PLANS: We will modify the atmospheric boundary conditions of the transport model SWMS_2D by adding the mass and energy exchange model of van Bavel and Hillel (1976). The modified model will allow the study of effects of dynamic weather conditions on water movement into and through the soil. We will add a two-dimensional corn root growth model (2DCORN) currently being developed as a distribution of water and chemical sinks. The completed model will allow simulation of water and chemical movement in soil as affected by spatially variable irrigation and climatic conditions, the effects of the soil environment on root growth, root water uptake, and root chemical uptake, and the effects of root distribution and water uptake on potential chemical leaching out of the root zone and into the groundwater.

QUANTIFYING CROP RESIDUE ARCHITECTURE AND REGULATION OF HEAT AND VAPOR FLUX

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CRIS: 5402-13610-003-00D

PROBLEM: Develop and implement a physically-based thermal module that simulates continuous thermal and water vapor dynamics in soil-residue-plant-atmosphere agroecosystems, using input and system parameters required by Root Zone Water Quality Model (RZWQM). The module should build on existing knowledge of theoretic principles and empirical observations to provide original results that fill knowledge gaps. Field data acquisition may be justified where required to test critical hypotheses. Simulation accuracy, including precision and bias, should be specified for bounded input and satisfy criterion established by RZWQM modules simulating plant development and biogeochemical transformations. Findings should be submitted for peer-review publication.

APPROACH: Simultaneous heat and water (SHAW) transport in the soil-plant-atmosphere continuum is simulated using numerical techniques to solve the continuity equations for heat and water flow. Components of the SHAW model will be incorporated into RZWQM, with the collaboration of Dr. Gerald Flerchinger, to enhance quantification of soil heat flux, a significant source of uncertainty in RZWQM. Knowledge of soil thermal profiles will also enhance simulation of biological processes such as plant phenologic development and biogeochemical transformations.

FINDINGS: Errors in the relation of plant canopy height to leaf area are corrected assuming self-similar scaling for canopy architecture. A quasi-empirical 'soil resistance' term in the ET module can be replaced with parameters defined in the modified RZWQM. Advances in turbulent transfer theory provides a rational basis for quantifying aerodynamic resistances from critical residue dimensions. An iterative solution to the Bowen ratio energy balance provides explicit coupling of soil heat flux and evaporative algorithms.

INTERPRETATION: None.

FUTURE PLANS: Existing data sets, quantifying effects of residue architecture on regulation of heat and vapor flux will be used to validate the thermal module. Field data acquisition will supplement simulation and validation activities to fill critical knowledge gaps in two areas: 1) within-canopy exchange processes and 2) effects of spatially variable site characteristics. Micro-tower instrumentation will feature automated, low-cost quantification of wind, thermal and vapor pressure profiles at multiple near-surface locations. These techniques can be readily applied to processes occurring in regions with spatially variable properties.

SEDIMENT INTRUSION AND DISSOLVED OXYGEN TRANSPORT IN THE SFSR SPAWNING AREAS

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CRIS: 5402-13610-003-00D

PROBLEM: The USDA Forest Service, Intermountain Research Station (INT) at Boise, Idaho, is conducting research to quantify the effects of eroded sediments generated by land use, storm events and wildfire on fishery resources of the South Fork of the Salmon River (SFSR). One important phase of this study requires accurate evaluation of the direct link between sediment deposition in salmon and steelhead spawning areas and fish survival and emergence. ARS has developed the only available sediment intrusion and dissolved-oxygen transport model (SIDO) that provides a means to help make this link. This prompted INT to enter into a cooperative research program with ARS to adapt the SIDO model to the conditions found in central Idaho.

APPROACH: A major goal was to extend the modeling approach used in the SIDO model to conditions prevalent in the SFSR. The plan of work also called for coupling the U.S. Army Corps of Engineers' HEC-6 sediment routing model and the U.S. Fish and Wildlife Service Instream Water Temperature model (IWTM) with the SIDO model to fit conditions in the Poverty spawning area. Because fundamentally different mechanisms of sediment intrusion are possible in the SFSR, the project involved investigating these mechanisms and revising the intrusion component of SIDO. We also assisted INT in the design of the field data collection program in the Poverty area. This field data was used to verify and validate the models.

FINDINGS: Modifications to the SIDO model and its coupling with the HEC-6 and IWTM codes are completed. Field testing of the modeling package as a whole has been pursued concurrently for the duration of the project. HEC-6 runs accurately reproduced water stage profiles measured in the Poverty area. Bed degradation simulations compared closely to a laboratory flume experiment. The bed armoring algorithms in HEC-6 did not satisfactorily simulate bed armoring compared to data from a flume study, but yielded reasonable characterizations of bed armoring in the San Luis Valley Canal, Colorado. The sensitivity of the IWTM to selected meteorological variables showed the relative importance of air temperature data in model predictions of instream water temperature. Comparisons of SIDO computations with field data from the Poverty area showed that the mean sediment intrusion mass can be accurately represented through adjusting a single calibration variable. This variable has physical significance and has relatively low model sensitivity. In addition, the model provided a reasonable estimate of the spatial variability shown by the field data.

INTERPRETATION: The assumptions underlying the HEC-6, IWTM, and SIDO models appear to be justified for the stated purposes. The verification and validation tests conducted so far indicate that using these models in a coupled mode is suitable for determining the impact of sediment intrusion on the SFSR spawning grounds.

FUTURE PLANS: All the associated software was implemented on the computer system at the INT, and training sessions were held at Boise to ensure proper technology transfer. Reports and papers documenting this work have been completed and the project terminated.

OPUS MODEL COMPLETION AND APPLICATIONS

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CRIS: 5401-13610-003-00 D

PROBLEMS: A variety of problems require information about the hydrologic and chemical status of an agricultural field, including:

1) determining seedling germination and plant establishment potentials
2) predicting future soil/crop status to aid in compliance decisions
3) global change.

The global changes predicted by General Circulation Models (GCM's) will inevitably affect the sustainability of agriculture throughout the world. Our problem is two-fold: first, we must predict the nature and severity of these effects; then we will provide guidance on mitigating management practices to optimize agrigultural productivity and environmental quality under the new climatic and atmospheric regimes.

APPROACH: Numerous agricultural problems can be approached with the application of computer simulation models. Opus is a model of an agricultural field, through the depth of the root zone. Model components include the hydrologic system, crops, management practices, erosion, and chemical fate.

FINDINGS: Opus is being applied in all of the above problem areas. The model has been successfully validated under several conditions. Documentation was completed this year with the publication of two volumes: one describing the model (by. R.E. Smith, USDA-ARS), and the other detailing computer program use. A paper was written comparing pesticide fate predictions of Opus and GLEAMS relative to their respective hydrologic components. A journal article is in preparation.

In the Global Change-Hydrology area, the RZWQM was applied to a GCM-predicted change scenario. A 'base' run was made, simulating growing-season hydrologic conditions on a corn field that was intensively monitored in Watkinsville, GA. Maximum and minumum daily air temperatures were then increased by 3°C, and precipitation was decreased to .9 of the original.

INTERPRETATION: Opus has been shown to be a useful applications tool in a variety of studies. Its strengths include the range of acceptable input data (e.g., from no rainfall data to daily to breakpoint, depending on user objectives and data availability), the model's physical basis with empiricism and stochatic strategies embedded where necessary, relative ease of use, and reasonable predictions.
The RZWQM Global-Change application indicated the compound effects of temperature raising and precipitation lowering, including a 19% decrease in runoff.

FUTURE PLANS:

(1) The Germination/Establishment project is in cooperation with Gary Frasier, USDA-ARS. First, weather data for Great Plains sites is being analyzed for the frequencies of germination/establishment conditions. Then Opus will be run for long periods using NWS rainfall data from various Great Plains sites. It will also be run for hundred-year periods using internally-generated weather data. Predicted soil moisture/temperature data will be analyzed to determine frequencies of potential germination and establishment occurences for range grasses.

(2) Travis James, USDA-SCS-Colorado State Office, has requested additional strategies to employ when determining compliance. We are testing two methods: (a) running Opus using both internally-generated and available long-term weather data, then analyzing frequencies of required crop conditions; and (b) analyzing frequencies of weather conditions that affect crop germination and establishment, using available Colorado weather data.

(3) Global Change-Hydrology research will continue with Opus application to the scenario tested with RZWQM. This work is being conducted in cooperation with Ma Qingli, visiting scientist from Zhejiang University, Hangzhou China, and Donn DeCoursey, TERRA Lab.

RUSLE MODEL DATABASE SENSTIVITY

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CRIS: 5401-13610-003-00 D

This work was carried out in cooperation with K. G. Renard, USDA-ARS, Southwest Watershed Research Center, Tucson, AZ.

PROBLEM: The amount of eroded material entering watercourses from agricultural areas is necessary information in water quality applications because sediment transports adsorbed agricultural chemicals. A commonly-used estimator of soil loss is the Universal Soil Loss Equation (USLE). This model has six parameters which are recognized as universally affecting erosion: A = RKLSCP, where A is the computed annual soil loss, R is a rainfall-runoff erosivity factor, K is a soil erodibility factor, L is the slope length factor, S is slope steepness, C is a cover-management factor, and P is a supporting practices factor. The quantification of these factors requires a series of complex procedures.

APPROACH: Recent efforts by USDA and university cooperators produced RUSLE, the Revised USLE. RUSLE is a computer model which facilitates the quantification of USLE factors and the prediction of annual soil loss. Embedded within the RUSLE model are three databases, describing numerous location attributes (by city), crops, and management operations. Model results provide users with estimates of the relative effects of management practices. RUSLE is currently under consideration for adoption by the USDA-SCS-TISD.

Sensitivity analysis indicates the sensitivity of model output (predicted soil loss) to changes in input. The analysis guides users in determining the data in which to invest time and resources when preparing a model application.

A study was designed, implemented, and completed to determine the sensitivity of selected parameters and variables in RUSLE input databases. The site and conditions for the simulations were chosen in cooperation with G. Weesies, USDA-SCS. The base run was near Chicago, IL, on a corn field with Tama soil (silt), hydrologic soil group C. Field topography consisted of three segments: 125 ft at 5%, 100 ft at 3.5%, and 125 ft at 3%. The field was countoured with 3-in ridges with a 2% furrow grade. Field operations consisted of fertilizer application, tandem disk, field cultivator, spike harrow, row planter, and harvest.

FINDINGS AND INTERPRETATION: Changing the Citycode parameter results in changes in the entire suite of parameters and variables in the City Database. The model was very sensitive to Citycode changes from the base, Chicago, to Milwaukee, Madison, Indianapolis, Dubuque, and Fort Wayne. Indianapolis, for instance, produced over 30% greater soil loss than the base Chicago run; this is explained by greater rainfall (by about 20%), much of which occurs during the winter and spring, when the ground is exposed and vulnerable. RUSLE was much less sensitive to changes in EI Distribution Code; it was found that distributions from as far away as Denver produced little change in soil loss. Using the EI distribution

from the Pacific West, however, produced dramatic (over 50%) decreases in soil loss. The model was very sensitive to changes in air temperature: a -20% change in soil temperature caused bout -55% change in soil loss. A 20% temperature increase caused 40% increase in soil loss. This is explained by associated changes of residue decomposition rates, resulting in changes of vulnerability of soil surface conditions.

INTERPRETATION: The sample results above indicate the usefulness of sensitivity analysis for guiding users in their selection of input data. It is stressed that the results are site- and condition-specific, and that users should perform a limited sensitivity for their circumstances.

FUTURE PLANS: Such analyses should be performed under a variety of conditions for all input data. The present project can serve as a model for conducting, analyzing and reporting future work.

CHARACTERIZING MANAGEMENT - TEMPORAL AND SPATIAL VARIABILITY IN SOIL HYDROLOGIC PROPERTIES OF FIELD SOILS

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CRIS: 5402-13610-003-00D
5402-13660-002-00D

PROBLEM: The pollution of surface and ground waters can, to a large extent, be prevented by good management practices. However, the spatial and temporal variability in soil water properties of the field soils and the complexity of the processes involved, have to be characterized and understood well before suitable management practices can be devised and applied. This project aims at gaining a better understanding and quantitative characterization of the variability and processes at the field scale, and their interactions with management practices.

Specific Objectives for 1992

1. Variability and interrelation of soil properties along a sloping catena landscape.
2. Develop simpler methods for characterizing soil water properties of variable field soils.

APPROACH, FINDINGS, INTERPRETATIONS

Objective 1

An intensive soil sampling program was begun in May, 1993, on the Central Plains Experimental Range (CPER) in section 21 North of the Pawnee National Grasslands. Three locations were selected for sampling. The locations, a north slope, a south slope, and a playa were sampled on a 5 X 10 grid (10 X 10 m for the playa). The coordinates of each grid point were determined using the global positioning system (GPS). At each grid point the soils were sampled in 15 cm depth increments with a 7 cm Giddings soil exploration probe. The depth to which each grid point was sampled was determined by profile depth. In some cases, where profile depth was not limiting, sampling was done to 100 cm. Each 15 cm soil increment was subsampled for analysis of moisture desorption, bulk density, texture, root mass, carbon and nitrogen.

Analysis is complete for all physical and chemical properties except moisture desorption. At this time, statistical analysis using the SAS statistical package has been conducted on bulk density and texture. Trend and geostatistical analyses will be conducted on all properties. Interrelation of properties and landscape positions is being looked at.

Objective 2

1.Relationship between initial drainage of surface soil and average soil-profile saturated conductivity. The measurement of soil hydraulic conductivity, and its spatial and temporal variability, by standard techniques is time consuming and expensive. With an objective to develop a simple field technique, we investigated answers to two questions: Is the change in soil water content of the surface soil, two days after a thorough wetting, related to an effective average saturated hydraulic conductivity, K_s of the soil profile? Can the water content data be used to estimate spatial distribution of this average K_s? The evaluation is based on a theoretical analysis, using finite-element numerical solutions, for a spectrum of different textured homogeneous soils, as well as experimental data of three U.S. soils and an international data set containing various soils. In most cases, there was a highly significant correlation between log-log transforms of an effective profile-average K_s (the steady state infiltration rate or the harmonic-mean K_s of the soil profile) and the initial two-day drainage of the surface soil. In three of the soils, the slope of these relationships was not significantly different from the homogeneous-soils theoretical value of 2.53, whereas the slope was not significantly different from an empirical value of 2.0 in all cases. Spatial distributions (fractiles) of the scaling factors of the profile-average K_s estimated from the surface water content changes in two days, using slope value of 2.0 to 2.5, were fair to good approximations to the measured distributions for most of the soils.

2. Using available water content with the one-parameter model to estimate soil water retention. The one-parameter model (GHM) purposed by Gregson et al. is based on the log-log form of the soil water retention curve, below the air-entry value of ψ, in $\psi = a + b$ in θ, where a and b are the intercept and slope respectively. A strong linear relationship observed between a and b was expressed as $a = p + q\ b$. Given this relationship, the GHM was derived as in $\psi = p + b$ (In $\theta + q$). Given p and q values for a soil or group of soils, only one value of the $\psi(\theta)$ relationship needs to be known to calculate the only unknown parameter in the model ----b, and hence, the entire $\psi(\theta)$. Typically, θ at the -33kPa matric potential (θ_{-33kPa}) is used as the known $\psi(\theta)$ value. Here we provide a regression relationship between b and the available water content (AWC) to estimate b, since in many cases the AWC is available in the soil survey reports whereas θ_{-33kPa} is not. Using the b thus estimated in GHM gives only slightly larger errors in calculating the water content at different potentials than when using θ_{-33kPa}. Further, we show that the intercept (a') and slope (b') of a log-linear model, in $\psi = a' + b'\theta$ are also linearly related and an alternate form of the one-parameter model (LLM) can be derived, in $\psi = p' + b'\ (\theta + q')$, which used AWC directly. The errors with this model are comparable to GHM. Unfortunately, LLM requires an individual - soil p and q values and due to more scatter in the intercept-slope relationship, pooled p and q values for a group of soils, are not as effective in LLM as they are in GHM.

3. Spatial variability of preferential transport in a field soil. The goal of this research was to study the spatial variability of preferential transport of a non-adsorbed solute on two scales, within plot and between plot. We investigated the contribution of porosity to preferential transport and variability. The soil at the site is a member of the Bosville fine sandy loam series (fine-mixed, thermic albaquic Paleudalfs). The surface soil texture is

fine sandy loam; from 25-30 cm the texture is fine sandy clay loam. Below that is clay loam. Strontium Bromide ($SrBr_2$) tracer was applied with a dye in a 100 or 50-mm pulse of water to eight double ring infiltrometers. After redistribution the soil within the rings was sampled at 0.1 m increments to a depth of 0.7 m. The soil was scraped at 20-mm increments to 0.2 m to reveal dye strains. Twelve samples were taken at each depth on a regular pattern with a coring device 27 mm in diameter. There were only a very few dye strains of root hairs, root channels, and pores in the plots to a depth of about 50 to 80 mm. Recoveries of Br to 0.7 m ranged from 33 to 80% applied. Br recovery was positively related to initial air filled porosity and total porosity. Recovery was inversely related to time required for the solute pulse to fully infiltrate. Where recovery was low, a large fraction of solute movement was probably through a network of interconnected mesopores less than 0.1 mm in diameter and, in the clayey subsoil, through cracks filled with fine sand. A smaller amount appeared to move through the soil matrix.

FUTURE PLANS: The new convergence scaling developed by us recently and possibly a modification of similar-media scaling technique will be used in conjunction with trend and geostatistical analyses, to quantify the variability and interrelations along the catena landscape. This pilot study will be extended later to the entire Great Plains. This characterization of variability will then be used with our point models, such as the RZWQM, to develop an integrated soil-water-plant-atmosphere model for a landscape scale. The rainfall-runoff and soil-water measurements made at the CPER site will be used to validate this model.

PREDICTION OF LONG-TERM CHANGES IN CARBON STORAGE AND PRODUCTIVITY OF U.S. SOILS AS AFFECTED BY CHANGES IN CLIMATE AND MANAGEMENT

J.D. Hanson and B.B. Baker

CRIS: 5402-11000-002-00D

PROBLEM: Climate change has become a major concern among many scientists. Atmospheric CO_2 concentration has increased 25% in the past 70 years. At present rates of increase, CO_2 will reach a concentration twice that of pre-industrial times within the next 75 years. Concentration of other greenhouse gases (e.g., methane, nitrous oxide, and chlorofluorocarbon compounds) are also increasing. Escalating concentrations of these gases absorb thermal radiation which subsequently warms the earth's atmosphere. General Circulation Models (GCMs) of the atmosphere suggest the average global temperature will increase by as much as 3 °C to 5 °C as atmospheric CO_2 levels double. GCMs also predict an increased rate of circulation in the global hydrologic cycle, which could lead to increased precipitation.

As CO_2 increases, plant communities will change and species will populate areas that were previously inaccessible. Other changes that could possibly take place include modified rooting patterns, increased seed germination and plant establishment, and increased nitrogen fixation. These changes could have direct repercussions on the Conservation Reserve Program aimed at returning marginal cropland to rangeland. Thus, the ultimate effect on rangeland could end up being positive especially for areas presently considered too dry for contemporary crop production. However, higher production does not necessarily mean increased agricultural sustainability. On the contrary, production increases could lead to decreases of soil organic matter and subsequent degradation of the rangeland ecosystem. If these systems are to remain stable, care must be taken to monitor livestock production systems for excessive removal of soil organic matter.

Specific Objectives During 1992

1. Assess the impacts of climate change on livestock and grassland production in the major producing regions of the United States and

2. Identify and evaluate adjustments in practices and government programs and policies that would facilitate adaptation to climate change.

APPROACH: A dual emphasis was used to conduct this project. We first set out to determine where grazing is the most economically important. As a result, we developed what we call the Range Dependency Index (RDI). A map of the index shows how important range cattle production (cattle not sold from feed-lots) is to many of the counties within the Great Plains and Northwest. In Nebraska, for example, the RDI reaches a high of 46%, i.e. 46% of the county's income is from the sale of unfed beef-cattle.

Our second emphasis was on evaluating how climate change will potentially effect those regions of the United States that have a high dependency on grazing cattle. During this phase of the project, much time was spent on validating our simulation tool to make certain it performed well enough to answer these important questions. Simulations were conducted for areas of the U.S. with high RDI values. Eleven indicators were examined to determine the fate of grazing lands under four different climate change scenarios. The indicator variables included: peak standing crop, carbon to nitrogen ratio, water-use efficiency, soil organic matter, soil inorganic nitrogen, intake of grazed forage, digestibility of the grazed diet, forage to supplement ratio, milk production, and cow and calf weights at weaning. The climate change scenarios were effective doubling of CO_2 (550 ppm) alone and changes in precipitation and temperature associated with an effective doubling of CO_2 as predicted by three general circulation models: Geophysical Fluid Dynamics Laboratory (GFDL), Goddard Institute for Space Studies (GISS), and the United Kingdom Meteorological Office (UKMO).

FINDINGS AND INTERPRETATIONS: Doubling of CO_2 alone caused only slight increases of plant production, but when CO_2 doubling was coupled with changes in precipitation and temperature, plant production increased significantly. The most limiting factors on rangeland are moisture and available nitrogen. Thus as expected, moisture accounted for the greatest increases in plant production. Yet, wet/dry cycles have tremendous consequences on rangeland production. Normal, periodic drought is as important an issue as man induced global climate change when considering agriculture in arid and semiarid lands.

Generally, both plant and animal production responded positively to climate change for the northern latitudes. However, higher production did tend to reduce the soil organic matter, increasing the chance for system degradation. Sustainability of long-term agriculture is necessary for a stable agricultural economy within the United States. Therefore, we must consider not only short-term economic trends, but also long-term ecological stability. To safeguard rangeland, a system should be implemented for long-term monitoring of soil organic matter. Animal production was, however, severely hampered in the southern regions of this study. The primary cause was the direct effect of temperature on the animals and the indirect effect of temperature on forage quality. Management may, however, compensate for this problem by selecting other breeds of animals, particularly Bos indicus.

Six key points were inferred from these simulation experiments. Firstly, the climate-change scenarios tended to predict an increased length of growing season. Grasslands rely mostly on spring moisture while summers are generally very dry. The GCMs seemed to accentuate this pattern and as a result the growing season was longer (by some 30 days). Subsequently, production increased, particularly in the spring and fall. Secondly, animal production decreased for the California and Southern climate change scenarios. Reduced animal production occurred coincident with increased plant production because of decreases in soil inorganic nitrogen and concomitant decreases in forage quality. The availability of nitrogen in rangeland systems is a controlling factor and is closely related to the decomposition of soil organic nitrogen. Thirdly, livestock production tended to shift northward because of adverse conditions (primarily high temperatures) in the southern regions. Fourthly, climatic variance between years was slightly

greater for the scenarios than for the nominal run. If the variance for yearly production does indeed increase, then uncertainty regarding plant growth increases thereby resulting in uncertainty in management decisions. Fifthly, management will be able to compensate for climate change. Management of livestock will ultimately guide animal performance. In bad years the manager must either sell livestock or feed them. If vegetation production is more variable, then stocking rates must be decreased to reduce risk and to insure good animal vigor. And finally, intensive management costs money. The more intense the management, the more the cost to the operator. Thus, even though the livestock may perform at similar levels, in the end, beef productions costs may increase.

FUTURE PLANS: Changes in climate as predicted by climate models may lead to an increase in the degradation or desertification of semiarid rangelands. Our research in this area seeks to define potential adaptive management strategies that will ensure sustainable production in the face of transitory climate change for ranchers that are economically dependent on marginal range resources. The objectives of the study are to assess the impact of climate change at the scale of the individual rancher and to determine the appropriate adaptive management strategies to enhance sustainable cattle and rangeland production in response to transitory change in climate. Secondly, because marginal rangelands are particularly sensitive to both climatic and biological perturbations, we will assess the impact of these strategies on ecological processes of the rangeland system. We will conduct a simulation experiment using the SPUR2 grassland/cow-calf simulation model to simulate rangeland ecosystem response to changes in climatic conditions on a specific range site. Field data will be collected to parameterize the model and to allow for validation of model predictions for the first simulation year. The simulation site will be chosen based on the regional economic dependence rangeland production and ecological vulnerability to potential climate change. A Socio-Ecological Risk Index was developed in a Geographical Information System to locate counties that would be most vulnerable should climate conditions become more harsh. An economic analysis will be performed on the simulated data to determine the economic feasibility of the different management combinations. With this approach, we will be able to evaluate several alternative management strategies that will ensure sustainable agricultural production in regions where the socio-ecological risk of adverse effects of prolonged climate change is high. Secondly, this study will increase our understanding of how ecological processes of rangeland systems may be affected by potential shifts in climate. Finally, we will further study the linkages and feedbacks between management alternatives and ecological processes.

DEVELOPMENT OF A COMPREHENSIVE MODEL FOR SOIL GAS FLUX AND REACTION

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CRIS: 5402-11000-002-00D

PROBLEM: Fluxes of greenhouse gases are being measured at numerous places around the world. Data have shown that these fluxes exhibit a high degree of spatial and temporal variability related to the specific biological, chemical, and physical processes involved and to their controlling state variables. Adequate simulation of gas fluxes requires not only detailed knowledge of the dynamic biological and chemical processes, but also the physics of water movement, heat transport, and gas transport subject to atmospheric pressures and meteorological conditions.

APPROACH: Our detailed numerical models (NTRM-2D and RZWQM) of integrated processes associated with water and heat fluxes, nutrient cycling and soil chemistry, and crop and root growth are being extended to include soil gas fluxes and their interactions with soil biological and chemical processes. Methods are being used that are based on state-of-the-science knowledge of the production, consumption, and transport of these gases. Time step size will be optimized depending on specific process rates, and probably will range from weekly to less than daily. The model will be tested against data collected from our field research program in eastern Colorado and supplemented with other applicable data sets from the region. We will then use our extensive GIS database for Weld County, Colorado together with our knowledge and experience gained from related modeling/GIS research to link and run our integrated soil gas model for regional dryland and irrigated agriculture, and rangelands.

FINDINGS: 1. Modeling Activity

A comprehensive two-dimensional model for simulating production, consumption (absorption) and transport of greenhouse gases (e.g. CO_2 and CH_4), including N_2O and O_2, is currently being developed. A finite element numerical procedure is being employed to simulate simultaneous transport of soil gases (diffusion and advective-dispersive), and water, heat and solute transport provided by the NTRM-2D model in two dimensions. A one-dimensional model that simulates diffusion of CO_2 and O_2 was obtained from the University of Oregon. Presently, this model is being evaluated using the data that were collected from the experiments conducted in 1992 (see Section 2).

2. Field and Laboratory Activities

Profile sampling of CO_2 and CH_4 distribution in the soil were taken from three experiments laid out during the Spring and Summer of 1992. Data taken from these experiments will be used to validate the gas model being developed. These are:

2.1. Wheat-Tillage-Residue Experiment

The objective of this experiment was to determine the effects of tillage practices (till vs. no-till), surface residue cover (zero vs. double farmer's rate) and stages of wheat development on levels of CO_2 and CH_4 in the soil. The experiment was laid out in a randomized complete block design with 2 replications. Two gas probes were installed in each plot. Gas samples (10 ml) were taken at 2, 5, 10, 20, 50, 100 and 200 cm soil depths. Surface soil moisture was measured gravimetrically, and at different soil depths using a neutron moisture gauge. Thermocouples were installed at depths similar to that of the gas probe, and soil temperature was recorded using a Campbell 21X datalogger.

Results indicated profile differences in the levels of CO_2 and CH_4 between till and no-till, and zero and double the surface residue cover treatments. CO_2 levels in the soil varied from 1 to 8 $\mu g\ cm^{-3}$. Peak concentrations were observed between 60 to 80 cm depths in all treatment plots. Correlations are being determined between levels of CO_2 and CH_4 with changes in soil moisture and temperature observed at various depths in the soil. CH_4 levels in the soil varied between 2×10^{-3} to 2.3×10^{-2} $\mu g\ cm^{-3}$ in the soil profile. High levels of CH_4 were observed immediately after a rainfall event between the surface and 20 cm below the surface.

2.2. Fertilization, Irrigation and Soil Temperature Effects on Soil Profile Distribution of CO_2 and CH_4 in a Shortgrass Steppe

This experiment was conducted at the Central Plains Experiment Station (CPER) shortgrass prairie, located 5 miles north of Nunn, CO. The objective was to determine the interactive effects of soil moisture and temperature on soil profile distribution of CO_2 and CH_4. Three 1 m x 1 m (3.9 cm high) infiltrometer were installed in a fertilized plot and three in the adjacent unfertilized plot. Three gas probes, constructed similarly as those described in Section 2.1 but extended to 1 m length, were installed in each infiltrometer. Gas samples (10 ml) were taken at 2, 5, 10, 20, 50, and 100 cm depths by syringe suction. Thermocouples were placed at similar depths, multiplexed together with a Campbell AM416, and soil temperature was automatically recorded at 1 min interval using a Campbell 21X datalogger. Surface moisture was determined gravimetrically and surface temperature was measured using an Everest infrared thermometer.

Two wetting-drying cycles were made in the treatment plots; (a) 10 June - 9 July, 1992 and (b) 28 July - 27 Aug, 1992. Each infiltrometer was filled with 10.56 l water, to saturate the soil profile to a depth of 1 m, at the beginning of each period. Thereafter, soil profile measurements of CO_2 and CH_4, moisture and temperature were made at 2 days interval. Diurnal measurements were made on two dates within each of the wetting-drying event.

To monitor atmospheric conditions, a weather station was set up to automatically record incoming solar radiation, air temperature and wind speed at 0.5, 2 and 4 m heights above the ground surface, rainfall and ambient vapor pressure. Atmospheric pressure was taken during the gas sampling period using a Wallace & Tiernan altimeter calibrated to give atmospheric pressure. Atmospheric pressure output were corrected for air temperature and relative humidity changes.

Initial analysis indicated temporal and profile differences in the levels of CO_2 and CH_4 in the soil. At the surface down to 60 cm soil depth, CO_2 and CH_4 dramatically increased to their highest levels (CO_2 - 135 to 173 $\mu g\ cm^{-3}$ and CH_4 - 7 to 9 $\mu g\ cm^{-3}$) two days following complete soil saturation. With the soil profile drying, CO_2 and CH_4 levels, between the surface and 60 cm depth decreased dramatically. During this drying phase, the levels of CO_2 and CH_4 at depths of 80 cm and lower were consistently higher compared to the measurements obtained at shallower soil depths. Diurnal and seasonal changes in the levels of CO_2 and CH_4 in relation to changes in soil temperature and atmospheric pressure are presently being evaluated.

2.3. Topographic controls of gas movement in the soil

This experiment was also conducted in a shortgrass steppe (CPER), starting on 10 July, 1992, in a north-facing and south-facing slopes. In each slope position (summit, backslope and toeslope) in the two aspects, two gas probes (constructed similarly as those described in Section 2.1), a neutron access tube and soil thermocouples were placed. The soil depths, where gas samples and soil temperature measurements were taken, were similar to that given in Section 2.2. Profile sampling of CO_2 and CH_4 and measurements of soil moisture and temperature were made on three dates from the start of the experiment. These data are currently being analyzed in relation to variations soil physical and hydraulic properties intensively measured during the period of the study.

(Project in cooperation with L. Ahuja, G. McMaster, C.V. Cole, J. Hanson, and A. Mosier).

INTERPRETATION: Development of a comprehensive submodel for soil gas flux and reaction will provide a badly needed component for use in a variety of models including those projects working on soil gas contributions to global climate change and modeling research aimed at developing comprehensive process models for soil-root interactions and microbial ecology.

FUTURE PLANS: Model development will be accelerated with emphasis on the use of existing soil gas data. We will be developing both 1- and 2-dimensional models initially for use in RZWQM, NTRM-2D, and other comprehensive process models we have in progress. Interfaces will be developed with the OMNI nutrient and SOLCHEM chemistry modules already available in RZWQM. The field data collection program will be continued to collect necessary detailed information from typical agricultural management systems. Close collaboration will be maintained with other on-going soil gas research.

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Publications

Ahuja, L.R. 1992. Effect of surface soil management and plants on water and chemical transport in the root zone. AGU Fall Meeting EOS:232.

Ahuja, L.R. and Hebson, C.S. 1992. Water, chemical and heat transport in soil matrix and macropores. Chap. 1 in Root Zone Water Quality Model, Version 1.0, Technical Documentation. GPSR Tech. Rept. no. 2. pp. 1-26.

Ahuja, L.R. and Swartzendruber, D. 1992. Flow through crusted soils: analytical and numerical approaches. Adv. Soil Sci. pp. 93-122.

Ahuja, L.R. and Williams, R.D. 1992. Reply to "Comments on 'Scaling water characteristic and hydraulic conductivity based on Gregson-Hector-McGowan approach'" Soil Sci. Soc. Am. J. 56:1981.

Alonso, C.V. and Mendoza, C. 1992. Near-bed sediment concentration in gravel bedded streams. Water Resour. Res. 28(9):2459-2468.

Anderson, G.L. and Hanson, J.D. 1992. Evaluating hand-help radiometer derived vegetation indices for estimating aboveground biomass. Geocarto International 7:71-78.

Anderson, G.L., Hanson, J.D. and Hart, G.F. 1992. Developing relationships between green biomass and Landsat thematic mapper derived vegetation indices on semiarid rangelands. Pages 355-363 in: Vol. 4. Remote Sensing and Data Acquisition. ASPRS/ACSM/RT92 Technical Papers.

Baker, B.B., Bourdon, R.M. and Hanson, J.D. 1992. FORAGE: A simulation model of grazing behavior in beef cattle. Ecological Modelling 60:257-279.

Baker, B.B., Bourdon, R.M. and Hanson, J.D. 1992. Potential effects of climate change on weaning weight in the Great Plains. Western Section ALAS 43:214-217.

Bartling, P.N.S., Shaffer, M.J. and Follett, R.F. 1992a. NLEAP, Northeast Database, Version 1.2. Soil Sci. Soc. Amer. Madison, WI.

Bartling, P.N.S., Shaffer, M.J. and Follett, R.F. 1992b. NLEAP, Southern Database, Version 1.2. Soil Sci. Soc. Amer. Madison, WI.

Bartling, P.N.S., Shaffer, M.J. and Follett, R.F. 1992c. NLEAP, Upper Midwest Database - Update, Version 1.2. Soil Sci. Soc. Amer. Madison, WI.

Benjamin, J.G. and Ahuja, L.R. 1992. A Two-dimensional Corn Root Growth Model for Variable Soils. Agron. Abst. p. 211.

Erbach, D.C., Benjamin, J.G., Cruse, R.M., Elamin, M.A., Mukhtar, S. and Choi, C.H. 1992. Soil and Corn Response to Tillage with Paraplow. Trans. ASAE 35(5): 1347-1354.

Ferreira, V.A. and DeCoursey, D.G. 1992. Effects of potential climate change. Managing Water Resources During Global Change, American Water Resources Association, p. 257-258.

Ferreira, V.A. and Smith, R.E. 1992. Opus: An integrated simulation model for transport of nonpoint-source pollutants at the field scale, Vol. II User Manual. USDA-ARS, ARS-98. 197 pp.

Follett, R.F., Shaffer, M.J., Brodahl, M.K. and Reichman, G.A. 1992. NLEAP simulation of residual soil nitrate for irrigated and non-irrigated corn. Agron. Abstr. 84:277.

Hanson, J.D., Anderson, G.L. and Hags, R.H. 1992. Combining remote sensing techniques with simulation modelling for assessing rangeland resources. Geocarto International 7:99-104.

Hanson, J.D., Baker, B.B. and Bourdon, R.M. 1992. SPUR2 Documentation and User Guide. GPSR Technical Report No. 1. 24 pp, 1 diskette.

Havis, R.N. and Alonso, C.V. 1992. Gravel siltation mechanisms in salmonid spawning habitat. Proceedings of the 5th International Symposium on River Sedimentation, Karlsruhe, Germany.

Havis, R.N., Alonso, C.V. and King, J.G. 1992. SSAM, Salmonid spawning analysis model. Project Completion Report and Model Documentation, USDA-ARS/FS Cooperative Agreement INT-90480-IA. 143 pp.

Heathman, G.C., Ahuja, L.R. and Timlin, D.J. 1992. Soil column tracer transport in an artificial macropore. Agron. Abstr. p. 217.

Horton, R., Benjamin, J.G. and Nassar, I.N. 1992. Thermally-induced Water Movement Beneath Plastic Cover. Agron. Abst. p. 43.

Lapitan, R.L. and Shaffer, M.J. 1992. Hydrologic and topographic controls of NO_3-N movement in variably saturated soil-aquifer system. AWRA Abstrs. 28:32.

LeCain, D.R., Aiguo, L., Morgan, J.A. and McMaster, G.S. 1992. Long- and short-term acclimation of spring wheat to ambient and elevated CO_2: Gas exchange and development. Amer. Soc. Agron. Abstracts, p. 127.

McMaster, G.S., Morgan, J.A. and Wilhelm, W.W. 1992. Simulating winter wheat spike development and growth. Agric. and For. Meteorol. 60:193-220.

McMaster, G.S., Wilhelm, W.W. and Morgan, J.A. 1992. Simulating winter wheat shoot apex phenology. J. Agric. Sci., Camb. 119:1-12.

McMaster, G.S., Wilhelm, W.W. and Skinner, R.H. 1992. Comparison of equations for predicting the phyllochron of wheat and barley. Amer. Soc. Agron. Abstracts, p. 20.

Renard, K.G., Alonso, C.V., Willis, J.C., Garbrecht, J.R. and Mutchler, C.K. 1992. Status of instream flows and channel maintenance program: Agricultural Research Service. USDA Report No. ARS-101, p. 87-95.

RZWQM Team. 1992. The Root Zone Water Quality Model: Technical Documentation GPSR Tech. Rept. No 2. USDA-ARS, Great Plains Systems Research Unit, Fort Collins, CO. 236 pp.

RZWQM Team. 1992. The Root Zone Water Quality Model: User's Manual. GPSR Tech. Rept. no. 3. USDA-ARS, Great Plains Systems Research Unit, Fort Collins, CO. 103 pp.

Shaffer, M.J., Rojas, K.W. and DeCoursey, D.G. 1992. Chapter 4, Equilibrium chemistry processes (SOLCHEM). In Root Zone Water Quality Model. Version 1.0. Technical Documentation. GPSR Technical Report No. 2. USDA-ARS, Great Plains Systems Research Unit, Fort Collins, CO. p. 107-127.

Shaffer, M.J., Wylie, B.K. and Cranmer, B. 1992. Central Colorado Water Conservancy District Sustainable Agriculture Project Recommendations for 1992-1993. 6-8-92. USDA-ARS GPSR and CSU.

Shaffer, M.J., Wylie, B.K. and Brodahl, M.K. 1992. Spatial distribution of nitrate leaching "hot spots" along the South Platte River in Colorado using GIS. abstract, In South Platte River Basin: Uses, Values, Research and Management-Current and Future, Conf. Proceedings, R. Craig Woodring, ed., Colorado Water Resources Research Institute, Fort Collins, CO.

Shaffer, M.J., Rojas, K.W., DeCoursey, D.G. and Hebson, C.S. 1992. Chapter 5, Nutrient chemistry processes (OMNI). In Root Zone Water Quality Model. Version 1.0. Technical Documentation. GPSR Technical Report No. 2. USDA-ARS, Great Plains Systems Research Unit, Fort Collins, CO. p. 129-161.

Shaffer, M.J., Wylie, B.K., Follett, R.F. and Bartling, P.N.S. 1992. Using climate/weather data with the NLEAP model to manage soil fertility and nitrate leaching. Agron. Abstr. 84:23

Timlin, D.J., Ahuja, L.R. and Heathman, G.C. 1992. Preferential transport of a non-adsorbed solute: Field measurements and simulations using the Root Zone Water Quality Model. Agron. Abstr. p. 229.

Timlin, D.J., Heathman, G.C. and Ahuja, L.R. 1992. Solute leaching in crop row versus interrow zones. Soil Sci. Soc Am. J. 56:384-392.

Wiegand, C.L., Maas, S.J., Aase, J.K., Hatfield, J.L., Pinter Jr., P.J., Jackson, R.D., Kanemasu, E.T. and Lapitan, R.L. 1992. Multisite analyses of spectral-biophysical data for wheat. Remote Sens. Environ. 42:1-21.

Wilhelm, W.W., McMaster, G.S., Rickman, R.W. and Klepper, B. 1992. SHOOTGRO 2.0 Nebraska Agric. Expt. Sta., Computer Software CP12.

Williams, R.D., Ahuja, L.R. and Naney, J.W. 1992. Comparison of methods to estimate soil water characteristics from soil texture, bulk density, and limited data. Soil Sci. 153:172-184.

Williams, R.D. and Ahuja, L.R. 1992. Evaluation of similar-media scaling and a one-parameter model for estimating soil water characteristic. J. Soil Sci. 43:237-248.

Wylie, B.K., Shaffer, M.J. and Brodahl, M.K. 1992. Validation of nitrate leaching and economic analysis package (NLEAP) using residual soil nitrate (NO_3-N) from irrigated croplands in Colorado. Agron. Abstr. 84:24.

Wylie, B.K., Shaffer, M.J., Brodahl, M.K. and Wagner, D.G. 1992. Spatial distribution of nitrate leaching "hot spots" along the South Platte River in northeastern Colorado. AWRA Abstr. 28:65.

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MISSION STATEMENT

The research mission of the Rangeland Resources Research Unit is to develop an understanding of the interrelations of the basic resources that comprise rangeland ecosystems. Research is directed toward the development of science and technology that contributes to enhanced forage and livestock production and sustainable, productive rangelands in the Central Great Plains.

LEGUMES FOR RANGELANDS: DROUGHT RESISTANCE IN DRYLAND ALFALFA

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PROBLEM: Productivity of the short-grass prairie of the USA is limited primarily by water and N. Since N fertilization of rangelands in this region is not economically feasible, the possibility of introducing N-fixing legumes into the prairie is being investigated as a means for improving the quality and quantity of forage. Incorporating legumes into semi-arid rangelands will be difficult given the characteristic low rainfall of this region. Research has therefore been focused on drought resistance and growth of appropriate legumes under the characteristic semi-arid conditions of the Central Great Plains. Information gained from these studies will help evaluate how and under what conditions legumes may be successfully utilized for enhancing productivity while maintaining sustainability of rangelands.

APPROACH: Yellow-flowered, *falcata*-type alfalfa (*Medicago sativa* L. ssp. *falcata* (L.) Arcangeli) is known for its drought and cold tolerance. Some *falcata*-type germplasm is found in dryland alfalfa cultivars. Although more stemmy and less nutritious then standard hay-type alfalfa, the *falcata*-types offer considerable promise for the development of drought resistant cultivars that could be successfully used in rangelands. Little information is available concerning variability for drought resistance traits among *falcata*-type alfalfa accessions, or about how alfalfa performs on the short grass prairie. One plant trait, carbon isotope discrimination, may have important relevance to establishing legumes into typically droughty rangelands as it appears to have potential for characterizing plant water use efficiency. Water use efficiency is a difficult trait to measure in the field, although it should figure significantly into the identification of superior cultivars for establishment into rangelands. Studies have been underway for three years evaluating 1) genotypic variability for carbon isotope discrimination and growth among several alfalfa clones, and 2) performance of alfalfa and alfalfa-grass mixtures at the Central Plains Experimental Range (CPER). (Collaborators: C.E. Townsend and D.R. LeCain).

FINDINGS: Clonal variation has been found in several environments for carbon isotope discrimination in *falcata*-type alfalfa. These findings suggest that water use efficiency may be increased in alfalfa, which should improve the adaptability of these plants to semi-arid rangelands. Results of the carbon isotope discrimination work in *falcata*-type alfalfa will be presented and published at the XVII International Grassland Congress (Feb., 1993, New Zealand).

Results from the second year of the grass/alfalfa field study at CPER indicated growth of both alfalfa and crested wheatgrass were significantly enhanced when grown in association with one another compared to growth in monocultures. There was also evidence that N nutrition was enhanced for crested wheatgrass when grown in association with the alfalfa.

INTERPRETATION: *Falcata*-type alfalfa shows promise for use in semi-arid rangelands. Genetic variation appears to exist for water use efficiency, indicating this trait may be improved in cultivars developed for rangelands. Results of the field study of the alfalfa/grass mixtures confirm our hypothesis that the incorporation of alfalfa into rangelands should improve the N fertility of these semi-arid regions.

FUTURE PLANS: Further studies are needed to explore the physiological and genetic nature of the clonal variations in carbon isotope discrimination in the *falcata*-type alfalfa before any practical applications of our initial findings may be implemented in a breeding program. However, I have given this work a low priority status, and question whether more work in this area will be done in the near future. It has become increasingly clear from program reviews, discussions with other scientists and my own (limited) experience with dryland alfalfa that I should shift the focus of my studies away from basic, high risk research like carbon isotope discrimination and direct more efforts towards collaborative, more practically-applied studies. I will therefore direct more of my research emphasis to the following areas.

Data from the alfalfa/grass plots will continue to be evaluated and analyzed. We will have forage quality analyses conducted on some of the herbage samples collected from this study. After analysis, manuscript preparation will begin for publication.

Limited greenhouse studies will begin investigating the physiology of alfalfa accessions known to differ for persistence. These accessions have been evaluated in the field at the Central Plains Experimental Range for 14 years. Noticeable differences in persistence have been observed among these accessions. If we can determine one or two traits in the greenhouse that relate to field persistence, then we will have a powerful means for improving the persistence of dryland alfalfa cultivars.

Plans are currently underway in the Rangeland Resources Research Unit to conduct a group of collaborative studies evaluating both management and breeding issues related to utilizing legumes in rangelands. At the present time, three separate studies are being considered. They involve 1) establishing legumes into rangelands, 2) interactions of soil water and legume N fixing capabilities, and 3) practical aspects of grazing on rangelands inter-seeded with legumes. Other related collaborative studies may arise as our group sees the need. I will have a major role in the second study involving interactions of water and legume N-fixing capabilities. The aim of these studies is to obtain as quickly as possible the expertise and technology necessary to allow the practical incorporation of legumes into semi-arid rangelands.

RESPONSES OF RANGELAND GRASSES TO CO_2 AND TEMPERATURE

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CRIS: 5409-11210-001-00D

PROBLEM: Historical trends and current projections of future patterns in atmospheric CO_2 levels strongly indicate a continued enrichment in global CO_2. Projections of CO_2-induced climate changes are less certain, but include altered rainfall patterns and temperature regimes. As plant growth is responsive to CO_2, temperature and water, changes in atmospheric CO_2 and/or climate are bound to have significant impacts on plant productivity and species composition of some ecosystems. This is especially true for the short-grass prairie in the Central Great Plains of the United States, where plant species composition and seasonal growth dynamics are highly conditioned by already limited soil water supply. An understanding of how prairie grasses may respond to long-term growth at elevated CO_2 will be required in order to intelligently manage rangelands in future CO_2-enriched atmospheres.

APPROACH: Photosynthesis, growth, plant N uptake, water and nitrogen use efficiencies, and carbohydrate metabolism were evaluated in growth chamber-grown western wheatgrass and blue grama, important C_3 and C_4 grasses of the Central Great Plains. Measurements were conducted on plants grown in a native soil under various CO_2 and temperature regimes. The Grassland Ecosystem Model (GEM) was utilized to evaluate some of the gas exchange responses. (Collaborators: J.J. Reed, D.R. LeCain, H.W. Hunt and W.G. Knight).

FINDINGS: In measurements conducted for three years at the Duke Phytotron at Duke University, NC, gas exchange measurements indicated that photosynthetic capacity of both western wheatgrass and blue grama acclimated to long-term exposure to elevated CO_2, resulting in a down-regulation of photosynthesis. We further discovered that growth at temperatures 4°C warmer than current average ambient temperatures of the Central Plains Experimental Range (CPER, where the grasses grow naturally) also resulted in a down-regulation of photosynthetic capacity. Growth chambers at the USDA-ARS Crops Research Lab were retro-fitted with a computerized CO_2-control/monitoring system to conduct further studies on effects of CO_2 and temperature on acclimation of the two prairie grasses. In the second experiment conducted at the Crops Research Lab, growth and photosynthesis of both species were again found to be sensitive to CO_2 and temperature. In addition, long-term exposure to high CO_2 was generally found to increase total nonstructural carbohydrates (TNC) in leaves. For the range of temperatures examined, both growth and photosynthetic acclimation responses were most evident at the temperatures considered optimal for growth of these two range grasses.

INTERPRETATION: The results of both of these studies indicate that responses of plants and plant communities to proposed climate change/enhanced CO_2 scenarios cannot be predicted with confidence with most existing models and knowledge bases, but must incorporate an understanding of the kinds of acclimation responses we have seen in our work. A number of other studies have also reported that photosynthetic and growth responses of plants to different environments is

highly dependent on such acclimation responses, although the mechanism(s) behind these acclimations is still poorly understood. Acclimation responses to elevated CO_2 and temperature must be incorporated into plant models or new models must be developed if we hope to be able to predict with reasonable accuracy how future ecosystems might be influenced by enriched CO_2 atmospheres and climate change.

FUTURE PLANS: We have just begun a third set of growth chamber studies to evaluate both above- and below-ground responses of grass/soil systems to enriched CO_2. These studies will be funded by Grant # 92-37100-7670 of the NRI Competitive Grants Program/USDA, and will investigate the responses of below-ground processes including mycorrhizae and soil chemical and nutrient responses to elevated CO_2 in addition to above-ground processes related to photosynthetic responses, water relations and carbohydrate metabolism. The below-ground component will specifically examine over time the proliferation of root material and the degree of vesicular-mycorrhizal (VAM) infection. These measurements reflect our interest in evaluating photosynthate allocation between shoots and roots, and the consequences for VAM infection and nutrient acquisition in the two grass species as influenced by CO_2 and water availability. The GEM model will be employed to integrate resultant data toward projecting community-level responses to CO_2.

ALFALFA INVESTIGATIONS

C.E. Townsend
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CRIS: 5409-11210-001-00D

PROBLEM: The yellow-flowered alfalfas (Medicago sativa ssp. falcata) are better adapted than the purple-flowered alfalfas (Medicago sativa ssp. sativa) to the harsh range sites of the central and northern Great Plains. In general, improved germplasm of yellow-flowered alfalfa for use in a breeding program is not available. Therefore, germplasms for the development of varieties of yellow-flowered alfalfa or for crossing with purple-flowered alfalfa need to be synthesized.

APPROACH: In 1978, 73 entries of the yellow-flowered, purple-flowered complex were established in single row, replicated plots at the Central Plains Experimental Range. Seedling emergence and stand establishment were excellent for all entries. These same 73 accessions plus 24 more were established in a spaced-plant replicated nursery at Fort Collins. All non-yellow-flowered plants were rogued.

In the spring of 1992, 33 (15 ssp. varia, 13 ssp. caerulea, and 5 spp. falcata) were seeded in single row replicated plots at the Central Plains Experimental Range.

FINDINGS: The 73 entries in the 1978 planting were rated for stand persistence in May 1992. Entries differed significantly for stand persistence which ranged from 5 to 88% with a mean of 49%. Several entries had excellent persistence in all four replicates. Precipitation was adequate for flowering and seed production. There was, however, so much yellow blossom sweetclover in the area that the honey bees did pollinate the alfalfa.

Three other yellow-flowered germplasms (diploid, tetraploid, and creeping-rooted--ploidy unknown) were grown under pollination cages. Seed production in 1992 was much less than in 1991 and this was attributed to the cool, moist weather during the summer. These germplasms trace to the Fort Collins planting.

The 1992 planting at the Central Plains Experimental Range failed even with irrigation because of hot, dry, and windy weather during April and May.

INTERPRETATION: The entries from the 1978 CPER planting should provide excellent germplasm for developing cultivars adapted to the 30 cm precipitation zone of the central Great Plains.

FUTURE PLANS: Continue to increase the seed supply of the different germplasms. To assist in this effort we plan to get a seed increase in the Pacific Northwest.

PHYSIOLOGY AND GENETICS OF ISOFLAVONOID ACCUMULATION IN CICER MILKVETCH

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CRIS: 5409-11210-001-00D

PROBLEM: Cicer milkvetch (*Astragalus cicer* L.) is a potential forage legume in temperate environments. However, cattle and sheep may be photosensitized after consuming its forage. Cicer milkvetch is strongly perennial, possibly due to its ability to accumulate defensive isoflavonoids in roots and rhizomes. Pterocarpans, a subclass of isoflavonoids, are biologically active in part because they become radicals in the presence of light. We are investigating the physiology and genetics of isoflavonoids in cicer milkvetch, and determining if these compounds are photosensitizers.

APPROACH: Isoflavonoids from diverse genotypes of cicer milkvetch have been collected with HPLC. Isoflavonoids were purified and then identified with UV- and mass spectroscopy, and H-NMR. Experiments examining the influence of intra- and interpopulational, and interspecific variability have been conducted. Greenhouse and growth chamber experiments have been conducted testing the influence of genotype on the accumulation of isoflavonoids in response to stress level and timing of accumulation. The influence of potential genotype x growth temperature interaction on the accumulation of isoflavonoids has been conducted.

FINDINGS: In cicer milkvetch, we have identified the unreported pterocarpans maackiain and medicarpin, isoflavones cajanin, afrormosin, pseudobaptigenin, and biochanin A, and the previously reported isoflavans mucronulatol and astracicera-n. Additionally, we have isolated and identified a new natural product, the isoflavone astracicerone. Genotype, species, and genotype X environment interactions influence the accumulation of isoflavonoids in cicer milkvetch. Correlations between roots and leaflets for the accumulation of isoflavonoids were nonsignificant.

INTERPRETATION: The influence of genotype is paramount in the accumulation of isoflavonoids in cicer milkvetch. However, genotype x environment interactions are important. Selection for reduced accumulations of isoflavonoids in shoots should not decrease concentrations of isoflavonoids in roots.

FUTURE PLANS: Photosensitivity testing with several animal models will be conducted in 1993 to determine if isoflavonoids are photosensitizers. Studies investigating the influence of genotype, environment, and genotype x environment interactions will continue through 1993.

CICER MILKVETCH INVESTIGATIONS

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CRIS: 5409-11210-001-00D

PROBLEM: Considerable progress has been made in the "domestication" of cicer milkvetch. There is, a continual need (a) to improve seedling emergence and stand establishment and (b) to improve forage yield. Seedling tolerance to a post-emergence herbicide such as 2,4-D amine would be of substantial value for improving stand establishment.

A relatively new problem concerns the apparent photosensitivity reaction developed under some environments by sheep and cattle grazing pure stand of cicer milkvetch.

APPROACH: After significant genetic variability for the trait under investigation has been found, recurrent selection is used to select for the desired trait.

Photoperiod-Induced Dormancy in Cicer Milkvetch

FINDINGS: Spaced plants of the component polycross progenies of the cultivar Monarch were grown under irrigation and subjected to four treatments which consisted of removing the top growth on 18 July, 25 July, 1 August, or 8 August. The mean extended-plant height on 15 September for these four dates of cutting was 56, 49, 36, and 27 cm, respectively. More importantly, however, there was substantial variability among plants within each growth period for extended height. Environmental growth chambers were used to determine the influence of photoperiod on plant growth during mid- to late summer. The growth chamber treatments consisted of a constant-15-h photoperiod and a gradually increasing photoperiod equivalent to the natural day length at Fort Collins from 1 August through 15 September. Polycross progenies of selected germplasm and Monarch were used in these studies. Plants under the decreasing photoperiod treatment were used in these studies. Plants under the decreasing photoperiod treatment were significantly (P=0.01) shorter (23%) and produced significantly (P=0.01) less shoot-dry matter (25%) than those plants under the constant photoperiod. The decreasing photoperiod also produced fewer flowering plants and fewer racemes/-plant than did the constant photoperiod. There was considerable variability among plants under both photoperiods for extended height and shoot-dry weight.

The cultivar Windsor was officially released by the USDA-ARS and the Colorado and Wyoming Agricultural Experiment Stations. Mean plant green weight for the polycross progenies of the 15 parental clones of Windsor was 120, 110, 116, and 119% of that of Monarch for the first, second, and third harvests and for total yield, respectively. Mean extended plant height for the progenies was 109, 112, and 120% of that of Monarch for the first, second, and third harvests, respectively. Mean plant spread at the end of the second harvest year was 105% of that of Monarch. Seed weight of the parental clones ranges from 3.55 to 4.59 g/1000 seeds with a mean of 3.99 g, or 96% of that of Monarch. Mean seedling emergence for the 15 polycross progenies was 121% of that of Monarch.

INTERPRETATIONS: These studies demonstrate the presence of photoperiod-induced-dormancy trait in cicer milkvetch. Also, the improved forage yield of Windsor in comparison to Monarch demonstrates that the forage yield of cicer milkvetch can be improved by genetically removing the photoperiod-induced-dormancy trait.

FUTURE PLANS: These data have been summarized and the manuscript is in peer review. A registration article for Windsor will be prepared. The memorandum of understanding for the exclusive release of Windsor will be completed. Will file an application for the Plant Variety Protection Certificate for Windsor cicer milkvetch.

Selection for Tolerance to 2,4-D amine

The data from five cycles of recurrent selection have been analyzed, but not summarized. There were significant (P=0.05) differences among cycles for dry weight of top growth, dry weight of roots, total plant dry weight, plant height, and new growth from the apical meristem. Selection cycles did not differ for new growth from the crown meristem. The dry weight of the tops, roots, and total plants for the five cycles of selection when expressed as a percentage of cycle 1 are given below:

Selection cycle	Dry wt. tops	Dry wt. roots	Dry wt. total
1	100	100	100
2	103	97	100
3	110	115	112
4	118	119	119
5	124	119	122

INTERPRETATION: There were significant differences among progenies within cycle 5 for all traits except dry weight of roots. Consequently, there appears to be enough variability remaining to make additional progress for all traits except dry weight of roots and, of course, new growth from the crown meristem.

FUTURE PLANS: The data will be summarized and prepared for publication.

Cytogenetics of Cicer Milkvetch (cooperative with Dr. R.L. Latterell)

FINDINGS: The meiotic analysis of octaploid plants of cicer milkvetch has been completed. Features characteristic of all clones evaluated included strongly bivalentized chromosome pairing at first metaphase, regular disjunction at first anatelophase, and high pollen viability-plant fertility. Two contrasting patterns of meiotic behavior were distinguished among the clones based on their 1) degree of bivalentilization, and 2) inversely proportional frequencies of multivalents. It is possible that these differences reflect the influence of a control system which promotes bivalentization by inhibiting multivalent formation.

INTERPRETATION: These investigations explain earlier research showed that the loss of plant vigor upon inbreeding for cicer milkvetch was more similar to what would be expected from a diploid species than that from alfalfa, an autotetraploid.

FUTURE PLANS: These data have been summarized and submitted for publication. Cytological data for the polyhaploids are being summarized.

Tolerance of Cicer Milkvetch to Low pH Soils (cooperative with R.A. Bowman)

FINDINGS: The second phase of the study was completed, but the data have not been analyzed.

FUTURE PLANS: The third phase of the study will be initiated this winter. After the third phase is completed, the data will be analyzed and prepared for publication.

Germplasm Development

FINDINGS: Seed was harvested from the three crossing blocks established in 1991. The elite plants in these blocks were as follows: (a) 11 plants for superior height, (b) 33 plants for superior height and forage yield, and (c) 15 plants for superior spread and generally good vigor.

FUTURE PLANS: This germplasm will be released to the public.

EFFECT OF IMBIBITIONAL TEMPERATURE ON SEEDLING VIGOR

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CRIS: 5409-11210-001-00D

PROBLEM: Seedling mortality is a major reason for stand failure from direct seeded shrubs. To decrease mortality, ways must be found to increase post-germination growth. Seed imbibition temperature is one factor influencing early growth. We don't know how or why. Two alternative hypothesis suggested to explain the loss in vigor caused when winterfat seeds absorb water at warm temperatures are: (1) warm temperatures increase the rate of imbibition and rapid imbibition may damage seed membranes, or (2) waste respiration, exacerbated by warm temperatures, may decrease stored food.

APPROACH: Imbibition in winterfat seeds was investigated in cooperation with M.B. McDonald (Ohio State Univ.). In 1991 we found winterfat seeds, as with most other seeds, imbibe more rapidly at warm temperatures. EDAX analysis indicated possible excessive loss of minerals from seeds imbibed at warm temperatures. In 1992, we imbibed winterfat seeds and diaspores at 5 and 20°C, then analyzed the seed for cations to determine if seeds imbibed at 20°C had lower cation concentrations than seed imbibed at 5°C. In a related study winterfat seed respiration during imbibition, germination, and heterotrophic growth is being compared at 5 and 20°C using a Columbus Instruments respirometer. Twenty-seed groups were used in 1991, but seed-to-seed variability hid the true respiration picture. Therefore 1992 was devoted to equipment and methods improvements designed to measure respiration of individual seeds. A third group of imbibition studies compared the optimum imbibition temperatures for a variety of species - including agronomic plants for which optimum imbibition temperatures have been reported in the literature. The studies used the same methods as were used for winterfat and were designed to evaluate our experimental procedure and to provide a broader understanding of the influence of imbibition temperature on seedling vigor.

FINDINGS: There does not appear to be a consistent difference in cation concentration between winterfat seeds imbibed at 5 versus 20°C. There does appear to be significant loss of K at 20°C, but there is also significant loss of Ca at 5°C, and no temperature difference for the other cations. Respirometry improvements appear promising and we are now collecting data for individual seeds. These tests will continue through 1993. Our tests on the optimum imbibition temperatures for a variety of species are summarized in Table 1. The findings for agronomic species agree with values reported in the literature, which validates our study methods.

Table 1. Imbibition temperatures ranked by influence on post-germination growth (axil length) for six species[1].

SPECIES	TEMPERATURE (C)					
	5	10	15	20	25	30
WINTERFAT (Eurotia)	1	2	3	4	5	6
PROSTRATE KOCHIA (Kochia)	3	1	2	4	5	6
SPINY HOPSAGE (Grayia)	3	2	1	4	5	6
GARDEN BEAN (Phaseolus)	5	6	3	1	2	4
TOMATO (Lycopersicon)	5	6	4	2	1	3
CUCUMBER (Cucumis)	6	5	4	3	2	1

1. Rank 1 = temperature correlated with the greatest axil length. Seeds had about 20% moisture. Data for winterfat are an average of three replications among three ecotypes (Booth 1992). Twenty-five and 30°C were not tested for winterfat and the ranks for these temperatures are implied from regression equations. Temperature rankings for other species are from five replicated tests of one seedlot. Significant ($P \leq 0.05$) F-tests for regression analysis or for analysis of variance were obtained for all species. Note that data from one seedlot may not be characteristic of the species.

INTERPRETATION: The lack of differences in seed cation concentrations due to imbibition temperature suggest that rapid imbibition may not be the primary cause of reduced seed vigor when winterfat is imbibed at 20°C. It has been believed that cold imbibition was generally harmful to seed vigor. My co-workers and I have shown that each species has its own optimum imbibition temperature. This will have a significant influence on cultural methods as specific seed imbibition management techniques are developed.

FUTURE PLANS: Continue to collect data on winterfat seed respiration as influenced by imbibition temperature. We will also determine the optimum imbibition temperatures for some seedlots of sagebrush and bitterbrush. I will look for opportunities to cooperate with other seed physiologists to learn how and why the optimum imbibition temperature varies. Tentative plans have been made with Dr. Roland Abernathy, Univ. Wyoming, to compare (membrane) proteins among winterfat ecotypes having different optimum imbibition temperatures.

STUDIES OF BITTERBRUSH SEED DORMANCY

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CRIS: 5409-11210-001-00D

PROBLEM: The use of bitterbrush in revegetation projects and the analysis of bitterbrush seed quality is hindered by seed dormancy. Known chemical treatments to remove dormancy are only partially effective in enhancing germination, are banned for use on public lands, or are of questionable value for seedling establishment. There are two theories to explain bitterbrush seed dormancy. The hypoxia theory ascribes dormancy to coat-imposed embryo hypoxia. The alternative is that dormancy is due to a chemical inhibitor whose mode of action is not known. Our studies suggest that dormancy is not due to embryo anaerobiosis. We are testing for a site of action by a chemical inhibitor, and to learn if standard seed dormancy treatments stimulate the embryo or act on an inhibitor.

APPROACH: The hypothesis we are testing is that seed coat chemicals inhibit glycolysis. This is being tested by extracting the chemicals from the bitterbrush seed coat, separating these into phenolic and cucurbitacin fractions, and testing for glycolytic inhibition by analyzing for ethanol following anaerobic incubation of a yeast and sucrose mixture. We know that mixtures containing the extracts to have less ethanol ($P < 0.05$) than mixtures without extract, implying that chemicals in the bitterbrush seed coat have the potential to interfere with glycolysis. This year the test was made for 3 different ecotypes.

FINDINGS: Results have been mixed with lack of an inhibitor effect for one ecotype and reduced effect for ecotypes previously tested.

INTERPRETATION: Our lack of consistent results may relate to the variability in inhibitor concentration among seeds. We reviewed all previous work and concluded that we are following a logical research path, but that we may need to refine our methods.

FUTURE PLANS: We are working to improve our methods to better account for inhibitor variability among seeds. We do not plan to continue this effort beyond 1993 but will seek opportunities to cooperate with people interested in the biochemical mechanism of glycolytic inhibition in bitterbrush.

SEEDBED MODIFICATIONS FOR INCREASED SEEDLING SURVIVAL

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CRIS: 5409-11210-001-00D

PROBLEM: Seedling desiccation is a major reason for failure of direct seeded shrubs. Two ways to solve the problem are to increase the plant's capacity to obtain water (ie, improve seedling vigor), or to increase the water available in the seed microsite (Harper's "safe site"). The question in the latter case is how to practically and economically modify the seed environment. Obviously this has been a focus of concern for many years by many people and is the basis for such techniques as contour furrowing, pitting, land imprinting, mulching, deep furrow drilling, and punch planting. Because of the amount of work which has been done in this area, one must be careful to find a truly innovative, but promising research path. I propose to test:

I. A key improvement to punch planting (old technology)

II. Utilization of weed barrier fabric (new technology).

Punch planting was not widely accepted because punched holes sluff, covering seed / seedlings, and punch planting is too slow a method for planting grasses or agronomic crops. I suggest it is not too slow a method for shrubs and trees. The improvement I propose is to case the punched hole with a plastic tube or sleeve. Weed barrier fabric is being used extensively in windbreak plantings and horticultural applications. It conserves soil moisture by reducing evaporation from the soil surface and by preventing water loss to competing, undesirable plants. The use of weed barrier has not been tested for growing shrubs on mined land.

APPROACH: A hand tool was designed and constructed to punch and case a hole in one operation. A variety of plastic tubings were considered for use in casing punched holes and selection made on utility and economic considerations. A greenhouse study was conducted to evaluate the technique and to test 3 and 7-inch hole depths for sagebrush (very small seed) and for ponderosa pine (large seed). Open and self-closing hole casings were tested. Both types of casings were installed to have about 1 in. of casing projecting above the soil surface. Weed barrier fabric was tested in conjunction with the cased punch planting. A subsequent field study was installed to provide further evaluation of cased punch planting to compare two- and three-inch holes, and to test the use of weed barrier fabric for growing shrubs. All studies used pregerminated seed to prevent the occupance of more than one plant per hole.

FINDINGS: Extruded cellulosic tubing was selected as an effective casing material. The 1-inch, standard-walled (0.022 in.) tubing wholesales for $171 per 1000 ft (Sinclair & Rush, Inc. - April 1992 prices). Thus the material cost for a 2-inch tube casing is about $0.03. The tests indicate the concept of cased punch planting is workable. The casing prevents the hole from sluffing in - cased holes remained stable even under heavy sprinkling. Plants inside tubes did not over-heat and were able to obtain moisture not available to surface planted seeds. Seven-inch holes were too deep. In the field planting self-closing casings and half-inch diameter casings prevented rodent depredation to ponderosa pine

that was almost universal in other treatments. The few thinned walled casings that we tried were functional, performed better for self-closing tubes than the standard-wall, and cost less.

These cased punch plantings were made through weed barrier fabric which effectively controlled weeds and conserved soil moisture. The 2 practices do need to be used together. Seedling establishment in the field planting indicates that spot planting through weed barrier may be an effective shrub establishment shrub establishment method for several species.

INTERPRETATION: The results are encouraging and suggest the two methods tested both have potential for improving seedling establishment under difficult conditions. Cased punch planting should be tested to measure the effect on seed germination and the consequence of multiple seedlings per hole. An economical evaluation for the use of weed barrier on mined land should be made.

FUTURE PLANS: We will collect more data from the field planting and will test seed germination and the effect of multiple seedlings per hole in cased punch plantings. A proposal will be prepared for submission to the 1994 Wyoming Abandoned Coal Mine Lands Research Program to test the use of weed barrier to establish shrub patches on mined land and the economy of the method.

RUNOFF/INFILTRATION MANAGEMENT FOR IMPROVED FORAGE PRODUCTION

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CRIS: 5409-12130-001-00D

PROBLEM: Water is a limiting factor in plant survival and production in arid and semiarid environments. Increasing the plant and animal production from rangelands in these areas requires that we manage the limited water supply in the most effective manner. One problem is the lack of basic information on the plant production as a function of water availability. There is limited information that indicates that the productivity of some plant species can be significantly enhanced with only small increases in water availability. A better understanding of plant-water relationships will assist in the development of techniques for improving the forage quantity and quality from our rangelands.

APPROACH: By collecting excess overland flow from hillsides during precipitation events and placing the water into the soil profile on lower lying areas (terraces) the water can later be utilized by plants. Also known as runoff farming or water harvesting, this technique presents an opportunity to increase forage production and, by introduction of different plant species (legumes), improve the forage quality of an area.

FINDINGS: First year studies were completed in the evaluation of the effectiveness of using hillside terraces of native grass rangelands to supply supplemental water onto level bench terraces for increasing forage production of a cool season (common oats) and a warm season annual plant (pearl millet). No plants of the oats were established under natural rainfall due to a spring drought. Weed competition reduced the yield of pearl millet under both natural rainfall and when the water applied with a rotating boom rainfall simulator. There were no differences in forage production with either species on plots watered one or two times with the rainfall simulator. Water applied directly to the plot area with the simulator was sufficient to produce a satisfactory crop. Runon water from the runoff contributing areas represented less than 25% of the total water applied.

INTERPRETATION: At the study area on the CPER the soil texture is a type that requires a rainfall of at least 25 mm and a rainfall intensity in excess of 50 mm/hr before there is sufficient runoff from the native grass areas to be of potential benefit in a terrace system. Precipitation events of these characteristics do occur at the site but they are unpredictable in their timing. This makes it very difficult to develop a viable water management plan under an operational terrace system.

FUTURE PLANS: The study will be repeated in 1993 with the natural runoff areas. Further data evaluation will be needed to decide on the merits of the water application with the rainfall simulator.

SALINITY ASSESSMENT OF RANGELANDS USING RAINFALL SIMULATION

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CRIS: 5409-12130-001-00D

PROBLEM: There are estimates that as much as 40% of the salinity loading on the upper Colorado River basin comes from rangelands. It is believed that some of the salt release from these lands can be reduced through the implementation of best management practices. The exact mechanisms by which the salts are transported from the rangelands and the effect of various land management practices on changing the salinity levels in the runoff water are not fully understood.

APPROACH: The salinity of runoff water collected from a limited number of sites using a rotating boom rainfall simulator will be correlated with the surface soil chemistry. The studies will be concerned with correlating the relative ratios of the various chemical ions in the runoff water to the same ion on the soil complex.

FINDINGS: Cooperative studies were initiated with the Environmental Protection Agency (EPA), USDI-Bureau of Land Management (BLM), and Colorado State University to develop techniques to quantify the salinity of runoff water from rangelands. Initial efforts were directed toward assessing the state of the information that currently exists.

INTERPRETATION: A limited number of studies have been conducted in evaluating the salinity movement from rangelands. Most of these studies have been concerned with the total salinity level as represented by electrical conductivity measurements and are highly site specific in their findings. Studies are needed that look at the individual chemical ions and their interactions in a water phase representative of conditions occurring during runoff from precipitation events.

FUTURE PLANS: Detailed soil sampling of the upper soil layers will be conducted at potential rainfall simulation study sites in the Colorado River Basin near Grand Junction, Colorado. These sites were selected because of the belief that the soils derived from the Mancos shale in the area are potentially large contributors to salinity in the runoff water. The soil samples will be analysis for various water soluble anion and cations. This data will be used to develop a chemical ion salinity balance that can be used to predict the salinity of runoff water. The results of this chemical model will be verified using results runoff water analysis data collected from plots which are subjected to sprinkling with a rotating boom rainfall simulator.

MANAGEMENT OF SODIC BENTONITE SPOILS

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CRIS: 5409-12130-001-00D

PROBLEM: Bentonite mine spoils in the Northern Great Plains are generally saline-sodic and have a high clay content making them extremely difficult to revegetate and sustain production. A technology was developed using sawmill wastes as a spoil amendment that enabled improved spoil physical characteristics and revegetation. To prevent long-term degradation of spoil quality surface applied gypsum was used to ameliorate the sodic problems that were enhanced after revegetation.

APPROACH: Wood residue amended revegetated bentonite mine spoils were amended with surface applied gypsum in 1987 at the rate of 56 Mg/ha. This rate of gypsum was required to reduce the ESP to 15. Spoil samples were collected to assess spoil sodicity and revegetation biomass estimates were made to determine the effects of gypsum on forage production.

FINDINGS: Spoil and vegetation data collection was completed in 1991; however, completion of data evaluation and thesis preparation continued into 1992. Surface applied gypsum was effective in reducing spoil sodicity in the surface 45 cm of the profile under natural rainfall conditions. Vegetation production also responded to the gypsum amendment, reflecting the increased spoil-water content resulting from the amendment.

INTERPRETATION: A manuscript has been prepared on the spoil response to gypsum amendment and one is also in preparation dealing with the vegetation response to gypsum amendment. This study has demonstrated that gypsum can be effectively used as a spoil amendment after revegetation as a management tool to ensure the long-term sustainability of these revegetated ecosystems.

FUTURE PLANS: No further data collection on these studies will be carried out. Manuscripts will be completed and published during this next year. Long-term (10 yrs) wood residue decomposition will be evaluated in 1993. To achieve this, 192 buried litter bags will be removed from the study plots. This will represent the last efforts in a long-term research project that has led to the development of reclamation technology for thousands of hectares of abandoned bentonite spoils in the Northern Great Plains. This project has also shown that gypsum can be effective in reducing sodicity and improving soil-water relationships under a natural precipitation regime (without having to use supplemental irrigation). The decomposition data has enabled a better understanding of the rate of wood decomposition under semiarid conditions and has been useful to state agencies for developing programs for the disposal of tree trimmings and other yard wastes on land rather than in landfills.

HIGHLY ERODIBLE CROPLANDS: SOIL QUALITY AND ECONOMICS

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Rangeland Resources Research Unit

CRIS: 5409-12130-001-00D

PROBLEM: A better understanding of the factors controlling soil organic matter formation and its activity is necessary to protect and restore the soil quality of marginal, highly erodible cropland being reseeded to grass. Alternative management of these lands to enable their regeneration and provide economic benefits must be evaluated.

APPROACH: Field sites were established in 1987 at Egbert, Keeline, and Arvada, Wyoming. Treatments included (1) continuous wheat-fallow cropping of marginal land, (2) plowed native grassland cropped to wheat fallow, (3) reseeded grass established on long-term (60 yrs) wheat-fallow on marginal cropland, and (4) native grassland. Soil samples were taken at 2.5 cm depth increments for the A horizon and a composite sample collected of
the entire B horizon to assess changes in soil biological activity and chemical properties. Grass biomass production was also assessed on the native and reseeded grass treatments. We continued to fertilize one-half of the reseeded grass treatment in the spring with 34 kg N/ha to assess its influence on carbon, nitrogen and phosphorus activity and dynamics. We have evaluated the economic benefits that can be derived from the grass production on the reseeded grass stands on the marginal cropland soils.

FINDINGS: Analysis of the 1991 data have exhibited significant increases in total nitrogen, nitrogen mineralization potential, respired carbon, and inorganic phosphorus in the surface 2.5 cm of soil on the fertilized reseeded grass treatment compared to the continuous wheat-fallow treatment on the sandy loam soil at Keeline. In fact, total nitrogen and nitrogen mineralization potential of the fertilized reseeded grass treatment were not significantly different from the native grassland, for the surface 2.5 cm soil depth. Respired carbon and inorganic phosphorus were significantly higher in the surface 2.5 cm depth of the grass and grass-fertilized treatments compared to the wheat-fallow on the clay loam soil at Arvada. Inorganic phosphorus was not significantly different for these treatments than the native grasslands in the surface 2.5 cm depth. The plowed native grassland treatment that is being cropped to wheat-fallow has exhibited significant reductions in soil organic carbon, respired carbon, total nitrogen, and nitrogen mineralization potential compared to the native grassland (surface 2.5 cm soil depth). Some treatment differences for several of the parameters were also evident at the 5.0 cm soil depth, but in many cases these differences were not statistically significant.
Forage production value, either as hay or for grazing, from the reseeded grass treatments showed that these lands can produce greater economic gain for the landowner than can be achieved from wheat production. In fact, if one uses the past 10 years of wheat production data, prices, and deficiency payment averages, the forage value is about twice that of the wheat.

INTERPRETATION: The observed short-term improvements in soil quality suggest that these soils can be restored to productive sustainable lands. The economic analysis using average wheat production, wheat prices, deficiency payments, and dryland hay and grazing values in conjunction with forage yields produced on the reseeded grass treatments suggest that forage production is an economically feasible alternative use of these lands. If government deficiency payments were to decrease or be removed from wheat, economics benefits of forage would be much greater than that achieved from wheat, based on historic prices. Each year, in this region, there is a demand for supplemental forages because of limited or the untimely precipitation patterns.

FUTURE PLANS: We will continue the evaluation of soil quality parameters on the soils samples collected in 1992 and we will collect soil samples in 1993 for soil quality and aggregation distribution dynamics. We will also continue to evaluate forage production from the native and reseeded grass lands.

CONTRIBUTION OF LEGUMES TO THE RANGELAND ECOSYSTEM

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CRIS: 5409-12130-001-00D

PROBLEM: Dryland forage production in the central Great Plains is generally limited to improved grass species and native grasslands. With the development of drought tolerant legume cultivars, the potential to improve both forage quality and quantity exists. Little or no research has been done to evaluate the role a legume might play in improving the soil quality and the quality of the non-legume species in the plant community.

APPROACH: Preliminary studies were initiated to evaluate the role of a legume in improving the soil quality and forage quality of the non-legume species in a plant community. A reestablished cool-season grass community with cicer milkvetch interseeded by wildlife was used for the study.

FINDINGS: Soil dehydrogenase activity was higher when the plant community included cicer milkvetch; however, nitrogen mineralization potential and respired carbon dioxide showed little response to the presence of the legume. Nitrogen content of the Bromus inermis did not show any response to the legume.

INTERPRETATION: These studies were preliminary and have given us important information as to expected levels of the parameters measured and will guide us in developing detailed studies.

FUTURE PLANS: Studies will be initiated in the spring to assess the degree of nodulation present on the cicer milkvetch and the activity of nodules that are observed. Studies will also include more finite and detailed sampling of the soil and plant communities of both the cicer-grass community and a falcata alfalfa-crested wheatgrass planting. Preliminary studies will also be initiated on the establishment of drought tolerant legume species in introduced and native grassland ecosystems.

LONG-TERM GRAZING IMPACTS ON THE VEGETATIVE AND HYDROLOGIC CHARACTERISTICS OF A NATIVE SHORTGRASS PRAIRIE

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CRIS: 5409-31630-002-00D

PROBLEM: There currently exists a conception that long term heavy grazing has damaged both the vegetation composition and density and the water infiltration characteristics of the semiarid rangelands. One common statement is that with removal of the large grazing animals, (cattle), the areas will revert back to the pristine conditions.

APPROACH: The Central Plains Experimental Range (CPER) has four separate pastures that have experienced the same grazing intensity for the past 50 years, season long -light, -moderate, and heavy, and yearlong-moderate. A 3 ha exclosure was constructed in each pasture to exclude large grazing animals. Within each exclosure a rotating boom rainfall simulator was used to measure the runoff/infiltration rates. Also measured was soil porosity, soil bulk density, soil particle size, and soil organic matter, all at 4 separate depths. The bulk density and particle size was measured both in the interspaces and under the grass clumps. Vegetation density, composition and production was measured in each exclosure. Slope and surface roughness measurements were made on each simulator plot. These measurement replicated in time will be used to evaluate the rate and extent of changes that might occur with the removal of the large grazing animals.

FINDINGS: First year studies were conducted in each of the exclosures. Preliminary data analysis shows an increase in runoff with increased past animal grazing intensity. Other data analysis and correlations have not been completed.

INTERPRETATION: Data interpretation will have to wait for time (additional years) to evaluate the rate that changes might occur.

FUTURE PLANS: The studies will be continued for a minimum of three more years.

GRASS: GRAZING RATES AND SYSTEMS STUDY

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CRIS: 5409-31630-002-00D

PROBLEM: Exaggerated claims for the benefits of short-duration rotation grazing systems have received a great deal of publicity and some official recognition by SCS and other agencies. A study was begun in 1982 to evaluate the response of cattle, vegetation and soils to three grazing systems at three stocking rates.

APPROACH: Crossbred and Hereford steers initially weighing 307 kg grazed native range 9 June-1 October 1992. Systems included continuous or season-long grazing (CG); rotationally deferred grazing in which grazing was deferred on one-fourth of each pasture until 12 August (RDG); and 8-paddock short-duration rotation grazing (SDRG). Grazing periods on the latter were adjusted according to assumed forage growth rate and forage supply, and ranged from 2 to 10 days in 1992. Light-, moderate- and heavy-stocked pastures were 40.9, 12 and 9 ha, respectively. Stocking rates in 1992 were 17.5 (light), 47.5 (moderate) and 63.3 (heavy) steer-days/ha. Steers were weighed every 28 days.

Peak plant biomass production was estimated inside 4 exclosures per pasture 28-30 July. Biomass remaining after grazing was estimated 28 September and 1-2 October. In July, yield was estimated on two 0.2 m^2 quadrats inside each exclosure with an electronic herbage meter. One quadrat was clipped in every fourth exclosure and weighed; the regression of weight on meter readings from these quadrats was used to estimate weights on the remaining quadrats. A similar procedure was used in September with five quadrats outside each exclosure. Correlations of weight and meter readings (r^2) in July and September-October were 0.89 and 0.81 respectively.

Cover of all plant species, litter and bare ground was estimated with an inclined point quadrat 29 June-1 July. Ten points were recorded at 50 locations along each of two transects (one on valley bottom, one on slope) in each light- and heavy-stocked pasture.

FINDINGS: Forage production averaged 840 kg/ha over all pastures; stocking rates and systems had no effect on production, actual or as percent of average production on the same pastures in 1982-1983. Forage utilization was 39% and 68% under moderate and heavy stocking, respectively; use under light stocking was so small as to be undetectable.

Effects of stocking rates and grazing systems on cover were:

Cover category	CG Light	CG Heavy	RDG Heavy	SDRG Heavy
	System and stocking rate			
	Cover, %			
Blue grama	3.0 b	4.8 a	5.4 a	4.6 a
Cool-season graminoids	3.7 a	2.1 a	2.2 a	2.8 a
Forbs	0.7 a	1.3 a	1.6 a	0.8 a
Total plant cover*	7.4 a	8.0 a	9.1 a	8.2 a
Litter cover	85.0 a	64.0 b	68.6 b	69.4 b
Bare ground	4.4 b	22.2 a	16.0 a	14.8 a

* Excludes mosses and lichens.

Average daily gains were:

Grazing system	Light	Moderate	Heavy
	Stocking rate		
	ADG, kg		
Continuous	0.95a	0.88ab	0.59c
Rotationally deferred	--	0.78b	0.56c
Short-duration rotation	--	0.63c	0.59c

INTERPRETATION: Cattle gains generally increased with decreasing stocking rate, but under short-duration rotation gains under moderate stocking were not significantly higher than those under heavy stocking. Neither system nor stocking rate had any effect on forage production. Litter cover decreased and percent bare ground and cover of blue grama increased under heavy stocking. A trend toward more bare ground under continuous grazing than under the two other systems may be developing. Otherwise, no benefits of specialized grazing systems have been detected after 11 years.

FUTURE PLANS: This study will be continued through 1994. Stocking rates will remain at 1991 levels. Originally it was planned to end the study in 1993, after three full cycles of rotational deferment. However, we were unable to recruit a graduate student this year to carry out two years of detailed vegetation measurements, so the study will be extended. If request for funds is granted, a second graduate student will be recruited to study C and N cycling.

LONG-TERM GRAZING INTENSITY STUDY, CPER

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CRIS: 5409-31630-002-00D

PROBLEM: Studies of the impact of grazing intensity on steer gains and range vegetation seldom last more than a few years. Data is needed on effects over several decades.

APPROACH: In 1949, a replicated study of 3 grazing intensities was set up at the Central Plains Experimental Range. Over the years replications were dropped until a single pasture of each of 4 treatments remains. The treatments are light, heavy and moderate stocking on summer-long (May to October) grazing and moderate stocking on year-long grazing. Steer gains were recorded in most years, and plant productivity and botanical composition were estimated by various means in some years. Initial measurements of botanical composition were by the "square foot density" method, comparable to basal cover.

In 1992, the summer light, moderate and heavy pastures were stocked at 15, 20 and 30 steers per 129.6 ha (320 acres), respectively. The year-long moderate pasture was stocked at 10 steers per 129.6 ha. Steers weighed 283 kg when grazing began 20 May 1992. Grazing ended on the summer grazed pastures 16 October 1992. Steers were weighed approximately every 4 weeks.

Basal cover of all plant species was estimated with a 10-pin inclined point quadrat. Cover was estimated at locations 5, 6, 7, 8, and 9 m from each of 20 permanent stakes placed in the large exclosure in each pasture, and the same distances from each of 20 cages outside the exclosure. Cover estimates are derived from a total of 1000 points inside and outside in each pasture.

FINDINGS: Stocking rates and steer gains were:

Treatment	Head/ 320 A	Head/ ha	Weight, kg 20 May	16 Oct	ADG
Year-long moderate	10	0.077	283	414	0.88
Summer light	15	0.116	282	395	0.76
Summer moderate	20	0.154	283	382	0.67
Summer heavy	30	0.232	283	369	0.59

For the summer grazing season, ADG = 0.98 - 1.82 (head/ha); r^2 = 0.93.

Forage production outside exclosures was 1010, 880, 750, and 1000 kg/ha on summer light, moderate and heavy and year-long moderate. Production inside was 960, 1210, 960, and 1500.

Cover class		Summer Light	Summer Moderate	Summer Heavy	Year-long Moderate
		% basal cover			
Bare ground	Out	20.3	25.9	25.1	19.9
	In	22.7	18.0	16.3	13.7
Litter	Out	47.8	39.0	38.6	42.5
	In	52.2	55.4	50.3	64.8
Blue grama	Out	16.2	27.6	24.4	18.5
	In	10.9	16.9	19.6	9.3
Western wheatgrass	Out	0.0	0.1	0.0	0.1
	In	0.1	0.8	0.3	0.4
Needle-and-thread	Out	1.3	0.0	0.0	0.0
	In	2.8	0.1	0.7	3.1

Cover class		Summer Light	Summer Moderate	Summer Heavy	Year-long Moderate
Sand dropseed	Out	1.5	0.4	0.9	0.5
	In	0.7	0.2	0.4	0.3
Sedges	Out	0.6	0.8	0.2	0.9
	In	0.6	2.3	1.2	0.3
Plains pricklypear	Out	3.5	1.3	2.1	0.6
	In	4.5	2.6	2.7	0.7
Fringed sagewort	Out	1.4	0.0	0.0	1.4
	In	1.8	1.6	1.7	3.6
Total plant	Out	31.9	35.1	36.3	37.6
	In	25.1	26.6	33.4	21.5

INTERPRETATION: Summer steer gains declined linearly with increasing stocking rate, with no indication that any rate was below the critical stocking rate. Forage production was higher under year-long moderate than under summer grazing. Total plant cover was lower inside than outside exclosures, except under heavy summer grazing. Cover of blue grama tended to be lower and that of needle-and--thread higher inside than outside. This confirms accepted theory that blue grama increases and needle-and-thread decreases under grazing at this location.

FUTURE PLANS: This study will be continued indefinitely. In the next year, manuscripts will be prepared showing the response of cattle and plant communities to date.

MONITORING RANCH-SCALE TIME-CONTROLLED GRAZING SYSTEMS

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CRIS: 5409-31630-002-00D

PROBLEM: Some producers and action-agency personnel have expressed doubts about the applicability of our grazing systems research, because pastures and paddock numbers are smaller than in most ranch-scale systems.

APPROACH: In 1990, the HR Land Co. (HR) established a 43-paddock time-controlled rotation grazing system on about 2225 ha (5500 A) of rangeland (R) and crested wheatgrass (CW) pasture east of Cheyenne. They invited ARS to monitor vegetation on the system. We established six 50-m cover transects in three paddocks of the system and placed an exclosure near each transect. Similar transects and exclosures were placed on adjacent land, grazed season-long, of the Wyoming Hereford Ranch (WHR) and Buddy Hirsig's ranch (BH). Peak standing crop, cover and utilization were estimated as in GRASS above; cover on 2 and 6 July, standing crop on 31 July, and utilization on 2 October 1992. Correlation of meter readings with standing crop (r^2) was 0.57 in July and 0.81 in October.

FINDINGS: Production and utilization were:

Vegetation type	Ranch	Production	Use
		kg/ha	%
Crested wheatgrass	HR	890	54
	WHR	920	23
Range	HR	720	56
	WHR	870	17
	BH	740	39

Cover estimates were:

Type	Ranch	Agde	Agsm	Stco	Total cool grass	Bogr	Total grass	Total plant	Litter	Bare
		%								
CW	HR	1.3	0.0	0.0	2.3	0.3	5.2	7.3	49.9	42.4
	WHR	1.6	0.0	0.2	1.8	0.6	6.0	8.0	60.2	31.2
Range	HR	0.0	0.6	1.4	3.4	4.3	7.8	7.9	64.5	26.1
	WHR	0.0	0.8	3.3	6.1	2.8	9.0	10.0	75.1	14.9
	BH	0.0	0.6	1.0	4.0	4.7	9.7	10.5	62.5	23.3

INTERPRETATION: Crested wheatgrass pastures are beginning the study in approximately equal condition on HR and WHR. Range on HR is similar to range on BH but in poorer condition than range on WHR. Use on HR was two to three times that on WHR; use on BH was intermediate.

FUTURE PLANS: Monitoring will continue on all three ranches for as long as present management continues. We will request information on stocking rates, grazing seasons and gains from the three landowners, and share our findings with them.

MODELLING PLANT AND ANIMAL RESPONSES ON RANGE

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CRIS: 5409-31630-002-00D

PROBLEM: Models are needed which are simple enough to run on desk-top computers with inputs readily available to the livestock producer, but complete enough to aid decision-making in livestock management.

APPROACH: The STEERISK spreadsheet as originally written was suitable only for semi-arid rangeland with predominantly spring and summer precipitation in the Central Great Plains. We tested the feasibility of re-parameterizing it for other rangeland locations around the western US. Gains and forage intake of steers, cover a range of stocking rates, grazing seasons, and initial weights, were simulated with the SPUR II model for locations in Rosebud County, Montana; Cherry County, Nebraska; and Sutton County, Texas. These locations represented northern mixed-grass prairie, sandhills tallgrass prairie, and desert grassland, respectively. Fifty years of simulations, with appropriate variability of forage production and digestibility, were run for each location x stocking rate x grazing season x initial weight. Regression equations were developed for each location to reflect the impact of management variables on the parameters of STEERISK.

FINDINGS: We found that very simple equations could describe the impact of management variables on the parameters of STEERISK at each location. Length of grazing season controlled critical grazing pressure (GP), average daily gain (ADG) at the critical GP, and both slope and intercept of the GP x ADG response curve at GP above the critical level. Slope was a function of the reciprocal of length of grazing season; intercept and ADG at the critical GP were linear functions of length of grazing season. Critical GP was calculated as the GP at which the regression line coincided with ADG at the critical GP. Initial weight of steers had a minimal effect on all parameters. Predictions of gains by STEERISKIER, the reparameterized STEERISK, were nearly identical with those by SPUR II; r^2 values were 0.980 for Nebraska, 0.992 for Montana, and 0.997 for Texas. SPUR II appeared to over-estimate forage production on the Texas site and the influence of forage digestibility on steer intake and gains, and under-estimated weight loss when forage was limiting. A manuscript was prepared, peer reviewed, and submitted to the XVII International Grassland Congress for presentation at the Congress and publication in the Proceedings.

FUTURE PLANS: SPUR II simulations of both steer and cow-calf operations will be run for each of the 46 Major Land Resource Areas in which range cattle production is a significant economic activity. The results will be used to parameterize STEERISKIER for each of the MLRA's. SPUR II may be modified to reduce the sensitivity of intake and gain to forage digestibility, estimate weight losses when forage is limiting, and provide more realistic estimates of forage production in sites in the Southern Great Plains, or other models may be tried. A wider range of grazing seasons and initial weights will be simulated where appropriate. Results will be published as a USDA publication if approved.

CHEW: CALF HUSBANDRY AFTER EARLY WEANING
CREW: COW RESPONSE TO EARLY WEANING

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CRIS: 5409-31630-002-00D

PROBLEM: Calves usually are weaned at 180 to 210 days old, in September or October. By this time amount and quality of forage is so low that weaned calves make little or no gain, and cows are slow to regain any weight lost during nursing. If calves were weaned earlier, any reduction in weight gain below that of unweaned calves might be compensated for by gain of cows, reducing cost of winter feed for cows.

APPROACH: Two 88-ha native range pastures were stocked at 5.2 ha/ cow-calf pair (moderate SR), and two 72-ha range pastures at 4.2 ha/pair (heavy SR) from 8 Jun to 7 October 1992. Each pasture contained 17 cow-calf pairs. Calves from one pasture at each SR were weaned 11 August at 118-179 days old; calves from the other pasture at each SR were weaned 7 October at 175-236 days old.
Early-weaned calves were held in dry lot and fed good-quality hay for two weeks, then divided into two groups of 17 calves each with approximately equal numbers from each SR. These groups were assigned to two previously ungrazed native range pastures of 10.2 ha each, one with three dry "mentor" cows and one without cows, at 0.6 ha/calf. Cows and calves were weighed about every 28 days. Forage production was estimated as in GRASS, with four exclosures per cow-calf pasture and three exclosures per weaned calf pasture.

FINDINGS: Forage production on pastures used for CREW, CHEW and SHAG was 820 kg/ha. Correlation of meter readings and standing crop (r^2) was 0.57.

Gains were:

Age class	Weaned	Stocking, post-weaning trt.	8 Jun - 11 Aug	11 Aug - 7 Oct	8 Jun- 7 Oct
			ADG, kg		
Cows	August	Moderate	0.50	0.17	0.33
		Heavy	0.55	0.07	0.31
	October	Moderate	0.62	-0.25	0.18
		Heavy	0.35	-0.75	-0.20
Calves	August	Moderate	1.00		
		Heavy	1.01		
		Mentor cows		0.03	0.60
		No cows		0.03	0.60
	October	Moderate	1.00	0.69	0.86
		Heavy	1.00	0.77	0.88

INTERPRETATION: August-weaned calves gained very little from weaning until October, while unweaned calves continued to gain, but not as fast as from June to August. By October, August-weaned calves were about 30 kg lighter than October-weaned calves, with no significant differences between stocking rates or between weaned calves with or without mentor cows. Cows whose calves were weaned in August continued to gain until October, while cows whose calves were weaned in October lost weight from August to October. Weight loss was greater under heavy stocking. Under heavy stocking, cows lost about 22 kg over the season. Under most economic conditions, the additional 30 kg of calf gain from October weaning should more than compensate for the cost of restoring 22 kg of lost weight to the cow.
The heifer calves from this experiment in 1991 were used for the SHAG study in 1992. Weaning date in 1991 had no effect on 1992 gains. In 1992, ADG of heifers weaned in July 1991 was 0.50 kg vs. 0.52 kg of heifers weaned in October 1991.

FUTURE PLANS: This study will be continued for two more years under approximately the same management and stocking rates. A graduate student will observe activity patterns of unweaned and weaned calves and will assist in interpretation of data and preparation of a manuscript, to include economic analysis of the results.

SHAG: SUPPLEMENTING HEIFERS FOR ACCELERATED GROWTH

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CRIS: 5409-31630-002-001

PROBLEM: For successful calving as 2-year-olds, British-breed heifers should weigh about 300 kg when first bred and 400 kg at delivery of their first calf. If these weights are not achieved, first calving may be delayed, delivery may be difficult, and condition of the heifer may be so reduced that rebreeding for the second calf may be unsuccessful. All these events increase costs and reduce profits.

APPROACH: Two native range pastures of 36 ha each were stocked with 16 yearling heifers each for a stocking rate of 2.25 ha/head. Pastures were grazed 10 June-7 October 1992. Beginning 20 July, heifers on one pasture were supplemented with free-choice high-energy blocks containing 15% crude protein. Forage production and supplement consumption were determined; heifers were weighed about every 28 days.
Heifers were exposed to bulls at 15 months of age. Subsequent breeding and calving performance will be related to treatment and gains.

FINDINGS: Forage production was 820 kg/ha. Supplement consumption averaged 0.5 kg/day. Heifers gained 0.49 kg/day without supplement and 0.53 kg/day with supplement; the difference was not significant. Mean weight on 7 October was 364 kg.

INTERPRETATION: Even though forage supply was less and stocking rate was higher than in 1991, supplementation still had no effect on gains. Apparently supplement substituted for forage rather than supplementing it.
Calving and rebreeding performance in 1992 did not differ between heifers supplemented or unsupplemented in 1991.

FUTURE PLANS: The study will continue for two to four years.

RANGELAND RESOURCES RESEARCH UNIT

Publications

Booth, D.T. 1992. Seedbed ecology of winterfat: Imbibition temperature affects post-germination growth. J. Range Manage. 45:159-164.

Booth, D.T. 1992. Bitterbrush seed dormancy - a Discussion. P. 208-211. In: Clary et al (Compilers). Proceedings - symposium on ecology and management of riparian shrub communities. General Tech. Report INT-289. USDA-Forest Service, Intermountain Research Station, Ogden, UT.

Hart, R.H., Bissio, J., Samuel, M.J. and Waggoner, J.W., Jr. 1993.Grazing systems, pasture sizes, and cattle grazing behavior, distribution and gains. J. Range Manage. 46:81-87.

LeCain, D.R., Aiguo, L., Morgan, J.A., McMaster, G.S. and Hendrix, D.L. 1992 Long- and short-term acclimation of spring wheat to ambient and elevated CO_2: Gas exchange and development. Proc. ASA Meetings, p 127.

Lenssen, A.W., Townsend, C.E. and Martin, S.S. 1992. UV exposure and incubation times influence accumulation of isoflavonoids in cicer milkvetch. Agron. Abst. 84:104.

Martin, S.S., Lenssen, A.W. and Townsend, C.E. 1992. Accumulation of isoflavonoid phytoalexins in diverse *Astragalus cicer*. Amer. J. Bot. 79 (Suppl.6):111.

McMaster, G.S., Morgan, J.A. and Wilhelm, W.W. 1992. Simulating winter wheat spike development and growth. Agric. and For. Meteorol. 60:193-220.

McMaster, G.S., Wilhelm, W.W. and Morgan, J.A. 1992. Simulating winter wheat shoot apex phenology. J. Agric. Sci., Cambridge 119:1-12.

Read, J.J., Morgan, J.A. and Harrison, P. 1992. Growth and gas exchange of blue grama (C_4) and western wheatgrass (C_3) under varying CO_2 and temperature regimes. Proc. ASA Meetings,
p. 130.

Samuel, M.J. and Hart, R.H. 1992. Blue grama growth in levels of western wheatgrass competition. J. Range Manage. 45:444-448.

Schuman, G.E., Bowman, R.A. and Reeder, J.D. 1992. Short-term edaphic response of marginal cropland to a reestablished grass community. Agron. Abst. p. 291.

Townsend, C.E. 1992. Seedling emergence of yellow-flowered alfalfa as influenced by seed weight and planting depth. Agron. J. 84:821-826.

Booth, D.T. 1992. Seedbed ecology of winterfat: Imbibition temperature affects post-germination growth. J. Range Manage. 45:159-164.

Booth, D.T. 1992. Bitterbrush seed dormancy - a Discussion. P. 208-211. In: Clary et al (Compilers). Proceedings - symposium on ecology and management of riparian shrub communities. General Tech. Report INT-289. USDA-Forest Service, Intermountain Research Station, Ogden, UT.

Hart, R.H., J. Bissio, M.J. Samuel and J.W. Waggoner Jr. 1993. Grazing systems, pasture sizes, and cattle grazing behavior, distribution and gains. J. Range Manage. 46:81-87.

LeCain, D.R., L. Aiguo, J.A. Morgan, G.S. McMaster and D.L. Hendrix. 1992 Long- and short-term acclimation of spring wheat to ambient and elevated CO_2: Gas exchange and development. Proc. ASA Meetings, p 127.

Lenssen, A.W., C.E. Townsend, and S.S. Martin. 1992. UV exposure and incubation times influence accumulation of isoflavonoids in cicer milkvetch. Agron. Abst. 84:104.

Martin, S.S., A.W. Lenssen, and C.E. Townsend. 1992. Accumulation of isoflavonoid phytoalexins in diverse *Astragalus cicer*. Amer. J. Bot. 79 (Suppl.6):111.

McMaster, G.S., J.A. Morgan and W.W. Wilhelm. 1992. Simulating winter wheat spike development and growth. Agric. and For. Meteorol. 60:193-220.

McMaster, G.S., W.W. Wilhelm and J.A. Morgan. 1992. Simulating winter wheat shoot apex phenology. J. Agric. Sci., Cambridge 119:1-12.

Read, J.J., J.A. Morgan and P. Harrison. 1992. Growth and gas exchange of blue grama (C_4) and western wheatgrass (C_3) under varying CO_2 and temperature regimes. Proc. ASA Meetings, p 130.

Samuel, M.J., and R.H. Hart. 1992. Blue grama growth in levels of western wheatgrass competition. J. Range Manage. 45:444-448.

Schuman, G.E., R.A. Bowman and J.D. Reeder. 1992. Short-term edaphic response of marginal cropland to a reestablished grass community. Agron. Abst. p. 291.

Townsend, C.E. 1992. Seedling emergence of yellow-flowered alfalfa as influenced by seed weight and planting depth. Agron. J. 84:821-826.

SOIL-PLANT-NUTRIENT RESEARCH UNIT

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MISSION STATEMENT

The mission of the Soil-Plant-Nutrient Research Unit (SPN) is to develop and evaluate new knowledge required to efficiently manage soil, fertilizer and plant nutrients (emphasis on nitrogen) to achieve optimum crop yields, maximize farm profitability, maintain environmental quality, and sustain long-term productivity.

GROUND-WATER NITRATE

Ronald F. Follett
Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-001-00D

PROBLEM: Managing nitrogen (N) for ground water quality is of increasing national concern, both among the general public and within the agricultural community. Important health concerns for quality drinking water in the USA must be balanced with the requirement to maintain and encourage a strong and economically viable agriculture. Central to the issue of managing N is contamination of ground water by nitrate. Nitrate, a highly mobile form of N, that can be leached through the crop root zone and eventually into ground water is a natural constituent in virtually all soils and waters and can arise from numerous sources.

The goal of any N management plan must include minimizing the leaching of nitrate from agricultural activities into ground water. Important aquifers underlie large areas of agriculturally important croplands and are estimated to supply about one-half of the supplies used in the USA. Ground water is a primary source of drinking and fresh water for both rural populations and many major cities.

APPROACH: Evaluation of the Nitrate Leaching and Economic Analysis Package (NLEAP) model is needed to determine its utility for assessment of N-management options. Data from a three-year field experiment of continuous corn (Zea mays L.) consisting of two blocks of plots, 'Site A' and 'Site B', were used. Half of the plots at each site were randomly chosen to be either nonirrigated or irrigated (based upon calculated potential evapotranspiration). Three replications of nitrogen (N) fertility (56, 112, and 224 kg ha^{-1}; 50, 100, and 200 Lbs ac^{-1}) were used. Soil was a Hecla sandy loam to loamy sand soil (Pachic Udic Haploborall). Soil and climate data were from the North Dakota portion of the upper Midwest database for NLEAP. On-site data were used when available. NLEAP was calibrated using Site A and validated using Site B. Required parameters were determined using Site A experimental data when otherwise unavailable or impractical to obtain.

FINDINGS: For corn grain yields, interaction of irrigation by years was highly significant at both sites; at Site B, response to N treatment was significant. Precipitation differences between yrs strongly influenced nonirrigated yields. The N uptake index, a 'sink' term, was significantly different from the NLEAP default when low grain yields resulted from dry conditions. High fertilizer-N rates resulted in high residual soil nitrate (RSN) levels following harvest. Predicted and observed RSN, across the three years for both Sites, were highly correlated.

INTERPRETATION: Results from this study show the need for careful attention to the use of sensitive parameters on this sandy soil, particularly the SWCPWP (soil water content at permanent wilting point) and NUI (nitrogen uptake index) values. Adjusting SWCPWP appeared to allow NLEAP to compensate for drainage and residual

nitrate movement from the soil profile; likely resulting from the nearness and fluctuation of the underlying water table. Experimentally measured NUI values, rather than the model default, were used to calibrate the model when early season crop N-uptake into the crop biomass was followed by dry conditions that result in low grain yields. Other conditions, where actual values of NUI might need to be used, could be for insect or disease infestations or for other grain-yield limiting situations.

Residual soil nitrate levels following harvest (RSN) were influenced by N-treatment and yr. N-management is necessary to lower RSN because of its vulnerability to leaching during the noncropped period of the yr. After calibration of NLEAP, correlations of predicted and observed amounts of RSN for all yrs and treatments at both sites were high. This study illustrates that NLEAP is adaptable to data collected on sandy soil under nonirrigated and irrigated conditions and for a wide range of N-treatments. Its output should be valuable to users as a decision making aid. Additional work is needed with NLEAP for other soils, N-sources, and economic crops to further evaluate its capabilities and limitations to help users assess various aspects of management to decrease N-leaching into ground water.

FUTURE PLANS: Future plans are to obtain an NLEAP assessment of the months most vulnerable to N-leaching below the crop root zone as it may assist in evaluation of potential BMP's.

DRYLAND CROPPING SYSTEMS

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CRIS: 5402-12130-001-00D

PROBLEM: It is projected that between 60 and 70 percent of all US cropland will be farmed with some type of conservation tillage by the year 2000. Tillage systems influence soil properties, N-use efficiency, and nitrate leaching. Consequences of widespread adoption of reduced-tillage practices on Great Plains soils is not adequately understood. Also not adequately understood are the consequences of long-term tillage on N-use efficiency and nitrate leaching in the Great Plains. Our objective is to determine N-pool sizes, seasonal or annual N-movement rates among various pools, and N-transformation processes in a wheat, sorghum (corn), fallow rotation.

APPROACH: A no-till dryland cropping rotation study was initiated at Akron, CO five years ago. The approach was: (1) to utilize ^{15}N isotope to study uptake of fertilizer-N versus soil N into growing crops, (2) to utilize isotopically labeled crop residues to study crop residue N movement into the subsequent crop(s), into microbial biomass, and/or active versus stabilized soil-N pools, and (3) to measure the movement of ^{15}N isotope from organic matter and fertilizer pools into a leachable mineral pool that has moved below the bottom of the crop root zone.
Five years have been used for data collection at the Akron site. Much of the analyses is either completed or being done. Plant samples were collected at boot, heading, and mature growth stages. Soil samples to a 150 cm depth, at 30 cm intervals were collected before and after harvest, and 10 cm depth samples were collected to correspond with plant growth stages for determining microbial biomass. These samples are mostly analyzed for ^{15}N, total N, and dry matter, and microbial biomass accumulation. N-uptake and N-utilization from normal abundance KNO_3-N and KNO_3-^{15}N fertilizer, applied in 1988 and 1989 is being assessed. The cropping sequence has been a wheat-sorghum-fallow-wheat-corn-fallow rotation.

FINDINGS AND INTERPRETATION: An efficiency of fertilizer N being recycled from the wheat straw to the subsequent sorghum crop that was grown in 1989 ranged from about 8 to 9%. Microbial biomass-C and -N have ranged from about 200 to 500 and 45 to 80 mg kg^{-1} of soil, respectively. There has been an increasing trend with time, likely as a result of decreased time in fallow with the current rotation vs. the previous wheat-fallow rotation that the field had been in. By 1991, there was a difference in microbial biomass C and N levels among N-fertilization rates. Uptake of ^{15}N by microbial biomass from labelled wheat straw applied to sorghum appears to be quite rapid. Concentration of ^{15}N in microbial biomass continues to increase through 1991, even though applied in 1987 or 1988. Use of fertilizer-^{15}N tracer to determine movement of fertilizer in the soil profile indicates there has been no leaching and most of the fertilizer N apparently stayed within the top 60 cm.

FUTURE PLANS: The plan is to now go into a longer-term observation phase for the field plots and to move ahead with data analyses and interpretation.

CHLOROPHYLL METER TO EVALUATE N-STATUS OF WINTER WHEAT

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CRIS: 5402-12130-001-00D

PROBELM: Spring application of part, or perhaps all, of the fertilizer-N applied to dryland winter wheat (Triticum aestivum L.) in the western Great Plains region may offer advantages to applying fall only N-application. A major advantage to spring-N application is that it allows evaluation of stand and stored soil moisture to be made first. An additional advantage is that of a shorter period of capital tie-up with spring N application compared to fall application. Research conducted in Colorado shows spring-applied N is equal, and in some cases superior, to fall application for increasing winter-wheat grain yield and protein content. These results indicate dryland wheat producers can use either fall- or spring-timing to apply fertilizer-N.

Use of soil and leaf tissue testing for determining crop N deficiency is widely accepted in the Great Plains. Soil samples taken to a depth of 60 cm have been used to develop a spring N fertilizer recommendation model. Likewise, fertilizer-N recommendations can be made with leaf tissue-N tests at the plant growth stage of Feekes 5. The primary problem with spring soil- or leaf tissue-tests is the time required for sampling, laboratory analysis and interpretation, and fertilizer-N recommendations by a farm advisor to the producer. Turnaround time for this service must be very fast or it will be too late to make a profitable spring fertilizer-N application.

The objective of this research is to begin quantifying relationships between yield, leaf N concentration, soil tests and the SPAD 502 chlorophyll meter readings for dryland winter wheat production. Specific goals were to evaluate the potential for calibration of chlorophyll meter readings with soil tests and leaf N concentration for the purpose of evaluating crop N status.

APPROACH: Four existing replicated N rate studies in Colorado were used to compare yield, leaf N concentration, soil tests and SPAD 502 chlorophyll meter readings of dryland winter wheat. The four sites are designated as Akron 1, Akron 2, Punkin Center, and Willard. The N fertilizer treatments for the Akron 1 location were 0, 28, 56, 84 and 112 kg ha^{-1}. The N fertilizer treatments for the Akron 2 location were 0, 34 and 68 kg ha^{-1}. The Punkin Center and Willard studies both had N fertilizer treatments of 0, 22, 44 and 68 kg ha^{-1}. The wheat cultivar TAM 107 was planted at all locations.

Readings were taken using a SPAD-502 chlorophyll meter at mid-length on the uppermost fully expanded leaf from approximately 20 randomly selected plants. Readings were avoided that would be directly on the leaf midrib. The leaf was removed from the plant by detachment at the leaf collar to facilitate ease of taking chlorophyll meter readings. The leaf was then saved for determination of leaf N concentration. The wheat plants were sampled on April 17 to 19 at approximately Feekes 5 Growth Stage. Nitrogen concentrations of leaf tissue were determined by automated combustion analysis. Soil samples for NH_4-N and NO_3-N

analysis were taken from each plot at the same time leaf samples were removed for meter readings and leaf N analysis. Soil samples (air dried) were analyzed for available NO_3-N and NH_4-N by a Technicon Autoanalyzer.

FINDINGS: Soil-N levels indicate that spring-N application should have benefited crop yields for the 0, 28, 56, and 84 kg ha^{-1} N-rate treatments for Akron 1 site, but would have only benefited the 0 N-rate at the Akron 2 site. Spring-N application should have benefited crop yields for all N-rate treatments at both the Punkin Center and Willard sites.

Leaf-N levels indicate that spring-N application would have benefited crop yields for the 0, 28, 56, and possibly the 84 and 112 kg ha^{-1} N-rate treatments for the Akron 1 site, but would not have benefited the N-rate treatments at the Akron 2 site. Spring-N application should have benefited crop yields for at least the 0, 22, and 44 kg ha_{-1} N-rate treatments and possibly all treatments at both the Punkin Center and Willard sites.

Comparison of chlorophyll meter readings and yield responses to fall-applied fertilizer N show that meter readings and yields both increased significantly between the 0 and 28 to the 56 kg ha^{-1} N at the Akron 1 site, with a leveling off of meter readings at about 42 to 44 with increasing N-rates. Meter readings ranged from 42 to above 46 at the Akron 2 site, with a significant increase between the 0 and 68 kg ha^{-1} N-rate treatments, but no significant yield responses to fertilizer N were observed. At the Punkin Center site meter readings ranged from about 43 to 48 and increased significantly between the 0 and 22 to the 44 kg ha^{-1} N-rate treatments; significant yield responses to fertilizer N were not observed because of the large variance in the yield data. At the Willard site, meter readings ranged from about 46 to 50 and increased significantly between the 0 to the 22 and 44 kg ha^{-1} N-rate treatments and with an additional increase at the 68 kg ha^{-1} N-rate treatment. Yield responses were similar with a significant increase between the 0 to the 22 kg ha^{-1} N-rate treatments and an additional increase between the 44 and 68 kg ha^{-1} N-rate treatments.

INTERPRETATION: In general, calibration of the SPAD-502 chlorophyll meter against yield, leaf N or available soil N (NH_4-N + NO_3-N) is possible. However, chlorophyll meter readings are expected to increase as soil-N availability increases. Crop-growth stage, differences in water availability between locations and soils under dryland farming conditions, and other soil-nutrient (especially phosphorus) availability may influence calibration of the SPAD-502 meter. Dryland climate conditions may be especially important when comparing meter readings taken at an early spring growth stage to grain yields. However, it is very important to obtain chlorophyll meter readings at an early growth stage (Feekes 5) while the wheat is still sufficiently early to respond to topdress-N fertilizer and to expect an economic yield response.

Spring application of part, or perhaps all, of the fertilizer-N applied to dryland winter wheat (Triticum aestivum L.) in the western Great Plains region may offer advantages to applying fall only N-application. In the current study a grain yield response might be expected for a meter reading of less than about 42. However, a significant yield response was observed at the Willard site with a meter reading of 50 compared to meter reading of 48 or less. Because a

chlorophyll meter provides a unitless indication of leaf greeness, utilization of this technology may require normalizing the data relative to an adequately fertilized area of the field.

FUTURE PLANS: Future plans are to continue field testing of the chlorophyll meter concept to include assessment N-fertilization in the spring and fall.

AMMONIA EMISSION FROM SOYBEAN RESIDUE DECOMPOSITION

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CRIS: 5402-12130-001-00D

PROBLEM: Ammonia (NH_3) may be the most important of the nitrogen (N) gases exchanging with the earth's surface in N-budget measurements between earth and atmosphere. Decay of crop residues is a major source of the N that potentially contributes to exchange of NH_3 between cropland soils and the atmosphere. When crop residues, especially legumes, are returned to the land as green manure, even larger amounts of NH_3 per unit of land area would be expected to evolve. In the United States, about 3,000 Gg of N are returned to cropland soil in crop residues each year; of which soybean residues alone account for about 23 percent.

Currently, there are few studies of NH_3 evolution from the decay of crop residues. The relative importance and interactions of factors affecting decomposition of crop residues and their contributions to NH_3 exchange to the atmosphere are likely quite complex. Our objective was to assess the importance of soil temperature, soil moisture, and crop residue addition rates on NH_3 losses from soybean residue amended soil.

APPROACH: Soil was a Weld silt loam. Soybean tissue and soil were mixed to obtain 5 or 2.5% by weight plant tissue to soil mixtures in pots. Individually each pot was placed in a desiccator and wet to either 100 or 60% of field capacity (FC) moisture levels for Experiment I with an additional treatment of 20% of FC for Experiment II. In Experiment I Coker soybean tissue was incubated single 7d incubation period during which time no air flowed across the soil surface; the incubation was followed immediately with a 4d dry-down period during which moisture- and NH_3-free air was passed across the soil surface at a constant flow rate. Ammonia liberated from the soybean:soil mixture was collected during the dry-down period. In Experiment II Tracy soybean tissue was used for four repeated wet-dry cycles, each consisting of a 7d incubation period followed by a 7d dry- collection period, and then rewetting to the original moisture treatment before the next cycle. Liberated NH_3 was trapped in 0.1M HCl in boats. All experiments were conducted in a constant temperature room.

FINDINGS AND INTERPRETATION: We found gaseous NH_3 losses from soybean:soil mixtures were highly associated with evaporative loss of water from the soil. More NH_3 is volatilized at FC than at 60 or 20% FC. We also found more NH_3 volatilized at 30°C than at 20°C or 10°C, and more at the 150g soybean rate than at the 75g soybean rate. This N loss is significant with four cycle repetition giving over 5% N loss for a 30°C, FC, 150g soybean tissue run. Since an estimated 3000 Gg of N are returned to cropland soils in soybean residues annually, then even a 5% loss is appreciable, and losses are likely much higher. Since our soybean tissue was obtained from tops after harvest, a greener manure would be expected to produce an even greater N loss. Analysis of the oven-dry soil following the incubation dry-down period showed significantly higher levels of NH_4-N at higher moisture level. This observation is consistent with data in Experiment II showing apparent increased rates of mineralization at higher mois-

ture level. We found that volatilized NH_3 from soybean-residue amended soil showed fractionation between ^{14}N and ^{15}N isotopes with the leading fraction lower in atom% ^{15}N than the trailing fraction. The fractionation parallels trends observed in steam distillation of NH_3, diffusion of NH_3, and NH_3 volatilization from senescing wheat.

FUTURE PLANS: Studies will be continued to assess the importance of depth of placement on the volatilization of NH_3 during crop residue decomposition.

ROLE OF ETHYLENE IN NODULATION AND NITROGEN FIXATION

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CRIS: 5402-12130-002-00D

PROBLEM: Ethylene is a powerful natural regulating substance that exerts a major influence on many aspects of plant growth and development. There is evidence that ethylene may regulate nodulation. 1) Ethylene inhibits nodulation in some legumes. In *Phaseolus vulgaris* nodulation was decreased 90% on explants exposed to 0.4 ppm ethylene. Whole *Pisum sativum* and *Trifolium repens* plants treated with ethylene had both fewer nodules and less nitrogen fixation than untreated control plants. 2) Nodulated *Medicago sativa* produces more ethylene than do non-nodulated plants. 3) Nodulated or nitrogen sufficient legumes produce enough ethylene to interfere with their own nodulation. In enclosed cultures, endogenously produced ethylene interfered with the nodulation process and reduced the nitrogen fixing ability of existing nodules on *T. subterraneum*. Also, *Medicago sativa* plants that produce 6.0 to 7.1 pmoles of ethylene per plant per hour were observed to form 5.1 nodules per plant. But, nodulation increased to 11.4 nodules per plant when ethylene production was decreased to 2.1 - 2.9 pmoles per plant per hour by the addition of aminoethoxyvinylglycine, an inhibitor of ethylene biosynthesis.

APPROACH: The objective of our CY-92 research with ethylene were to determine: 1) how much ethylene is produced by nodulated and non-nodulated roots, and 2) the effect ethylene has on nodulation. Two studies were conducted that examined the effect of nodulation on ethylene production by root. In the first study root ethylene production was measured using a open flow-through system that allowed ethylene produced by the root system to be trapped without disturbing the plant. For the second study, plants were grown in agar tubes containing O, 1, 10, 100 or 1,000 μM of ethephon (2-chloroethylphosphonic acid), an ethylene releasing compound and the effect on the plant evaluated by measuring plant growth, development and nodulation.

FINDINGS: In agreement with our earlier findings these studies indicated that the presence of nodules increased the production of ethylene. Uninoculated plants produced about 9 pmoles of ethylene per hour per gram fresh weight of plant material and inoculated plants produced about 31 pmoles. Our CY-91 and CY-92 research shows that this increase in ethylene production is due to the improved nitrogen nutrition of nitrogen fixing plants and to ethylene production by the plant portions of the nodule. Ethylene has been shown to be a strong inhibitor of nodulation in several legumes. Ethylene has been shown to inhibit nodulation in *Phaseolus vulgaris*, *T. subterraneum* and *Medicago sativa* and small amounts (2 ppm (14 μM) and above) of the ethylene-releasing substance 2-chloroethane phosphonic acid (ethephon) inhibited nodulation in *Pisum sativum* and *Trifolium repens*. This study examined the influence ethephon has on the nodulation of soybean plants inoculated with *Bradyrhizobium japonicum*. Soybean plants were inoculated with *B. japonicum* and grown for three weeks in the growth chamber in agar tubes containing O, 1, 10, 100 or 1,000 μM of ethephon. The treatment had a dramatic effect on several indicators of plant growth. Shoot

length was significantly reduced by 1 to 100 μM levels of ethephon. Internode length as well as plant wet and dry weights were similarly effected by ethephon. The highest ethephon level gave a distinct inhibitory effect on root length and lateral root formation. The trends observed with ethephon were not greatly influenced by the amount of nitrate-N (0.8 or 2.5 mM) supplied to the plants. In contrast to what has been observed with other legume systems, nodule number was not decreased by 1 to 100 μM levels of ethephon. Only the highest level (1,000 μM) inhibited nodulation. At this level ethephon also severely interfered with normal root and shoot elongation. Aminoethoxyvinylglycine (1 and 10 μM), an inhibitor of ethylene biosynthesis that has been shown to stimulate nodulation in *Medicago sativa*, did not stimulate nodulation in soybean grown on 0.8 or 2.5 mM Nitrate. The results show that nodulation in the soybean-*B. japonicum* system is not as sensitive to the effects of ethephon as are the *Rhizobium* systems that have been investigated in the past. Low and intermediate levels of ethephon do not interfere with nodulation in soybean although a dramatic influence on shoot and root elongation was observed. The trends observed with ethephon were not greatly influenced by the amount of nitrate-N supplied to the plants.

INTERPRETATION: The results with the ethylene studies demonstrate that nodulated soybean resembles other legumes in that nodulated plants produce more ethylene than non-nodulated plants. However, soybean differs from all other legumes studied to date in that its nodulation is not blocked by ethylene. Thus it does not appear that ethylene functions in the control of nodulation in soybean though it may have such a function in other legumes.

FUTURE RESEARCH: A manuscript has been prepared and is currently in journal review. No further research is planned with this problem.

ROLE OF THE *TRPCD* GENETIC REGION IN SYMBIOTIC NITROGEN FIXATION

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CRIS: 5402-12130-002-00D

PROBLEM: Recent research investigations have examined the role bacterial tryptophan biosynthesis plays in the *Bradyrhizobium japonicum*-soybean symbiotic association. There are several reasons to suspect that a product from this pathway may influence the symbiotic properties of the microsymbiont. First, mutant bradyrhizobia (auxotrophs) with defects in their tryptophan biosynthetic pathway often cannot nodulate (Kummer and Kuykendall, 1989). Second, bradyrhizobia with altered tryptophan catabolism have altered symbiotic properties (Kaneshiro, 1987). Third, research from this lab has demonstrated that, by altering the tryptophan metabolism of bradyrhizobia, bacterial inocula with improved symbiotic properties can be obtained. Plants receiving one such mutant (the NOD+ strain) have shown better color, higher dry weights and nitrogen content, and greater nodule number and mass than control plants inoculated with wild-type *B. japonicum* I-110. Data from these studies show that the improved nitrogen fixation observed with the mutant bacteria correlates with an increase in nodule mass due to increased nodule number (Hunter and Kuykendall, 1990). These observations suggest that a bacterial product made from tryptophan or made from a tryptophan pathway intermediate is involved in the nodulation process. The indole compounds that act as plant hormones are, of course, prime candidates.

APPROACH: The objectives of our CY-92 research with tryptophan biosynthesis were to develop tryptophan deletion mutants using marker exchange mutagenesis and to characterize these new mutants. These studies were conducted in collaboration with Dave Kuykendall. Genetic studies were performed in Beltsville and biochemical studies in Fort Collins.

FINDINGS: This study is concerned with examining the role of the *trpCD* genes in enhanced nodulation and nitrogen fixation. The *trpCD* genetic region of *B. japonicum* codes for two key enzymes in the tryptophan biosynthetic pathway. We are interested in the *trpCD* region because a *trpC* mutant was recently isolated that produced prototrophic revertants with enhanced nodulation and symbiotic nitrogen fixation (Hunter and Kuykendall, 1990; Kuykendall and Hunter, 1992). In order to evaluate the role of the *trpCD* region we have isolated and then deleted part of the *trpCD* genetic region from *B. japonicum*. The *Rhizobium meliloti trpCD* genetic region was used to identify homologous DNA from *B. japonicum* strain I-110. Marker exchange mutagenesis was performed. Working *in vitro* with a 5kb subclone from a cosmid, we deleted a *Sma*I fragment of high homology and replaced it with interposon omega carrying streptomycin and spectinomycin resistance. This plasmid construct, in vector pSUP202, was transferred to strain *B. japonicum* I-110AR, which has rifampicin resistance but is sensitive to streptomycin. Selection was on a tryptophan-supplemented medium. Trp^- mutants TA-12, TA-13, TA-14, and TA-15 grew on minimal medium (MM) plus tryptophan but did not grow on MM alone. Southern blot analysis confirmed that a genomic 1.2kb *Sma*I fragment within a 1.7kb *Sal*I fragment had been replaced by the 2.0kb interposon omega to generate an approximately 2.5kb *Sal*I fragment.

These auxotrophs grew on MM supplemented with indole but did not grow on MM supplemented with anthranilate. That the deletion mutants were blocked in the *trpD*- and *trpC*-encoded steps of the pathway was confirmed by biochemical analysis which showed they lacked both phosphoribosyl transferase and indoleglycerol phosphate synthase activities.

INTERPRETATION: The isolation of deletion mutants of *B. japonicum* that are missing the *trpCD* is a major step in developing bacteria that can serve as recipient strains for the *trpC* genomic region of the NOD+ (supernodulating) bacteria. There are two major reasons for transferring the NOD+ *trpC* region into other bacteria. 1) It would demonstrate that it is the *trpC* region of the NOD+ bacteria that is responsible for the enhanced nodulating ability of the NOD+ bacteria. 2) It would demonstrate that it is possible to transfer the supernodulating character to other bacteria -- thereby providing a means of genetically constructing new bacterial strains for use as legume inoculants.

FUTURE PLANS: A manuscript on these research findings will be prepared and submitted for review in CY-93.

A NEW PATHWAY OF IAA BIOSYNTHESIS IN BACTERIA

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CRIS: 5402-12130-002-00D

PROBLEM: The plant growth hormone, 3-indoleacetic acid (IAA), is biosynthesized by many microorganisms. It has been generally accepted that the biosynthesis of IAA involves tryptophan as a precursor. Recently a pathway was discovered in maize that does not involve tryptophan as a precursor (Science 254:998). Rather, IAA appeared to be synthesized from a compound made before tryptophan. The most probable candidate, other than tryptophan, for IAA biosynthesis is indoleglycerol phosphate (InGP), the *trpC* gene product. Our studies present preliminary evidence suggesting that such an alternate pathway of IAA biosynthesis may also exist in bacteria.

APPROACH: Both *Bradyrhizobium japonicum* and *Pseudomonas aeruginosa* were investigated. These bacteria were selected because of the availability of tryptophan pathway mutants. Four mutants of *B. japonicum* were used. These were a *trpC* mutant, that is unable to make indoleglycerol phosphate, and three *trpAB* mutants that do not have tryptophan synthase activity and are therefore unable to convert indoleglycerol phosphate to tryptophan. Two mutants of *P. aeruginosa* were used. One, a *trpA* mutant, is unable to make tryptophan since it lacks tryptophan synthase A. The other, a *trpF* mutant, cannot make carboxyphenylamino deoxyribulose phosphate (CdRP), indoleglycerol phosphate (InGP) or tryptophan.

FINDINGS: The presence of an IAA oxidase prevented detailed studies with *B. japonicum*. More detailed studies were conducted with *P. aeruginosa*. When grown in minimal media supplemented with tryptophan (MM+T) both *P. aeruginosa* mutants accumulated similar amounts of IAA. However, when MM+T media was supplemented with anthranilic acid, the *trpA* mutant accumulated more IAA than the *trpF* mutant. This stimulation of IAA biosynthesis in the *trpA* mutant by anthranilic acid addition suggests InGP is a precursor for IAA biosynthesis.

INTERPRETATION: The data suggest that a pathway for IAA biosynthesis that does not run through tryptophan may exist in bacteria. It appears that this pathway may involve InGP, the *trpC* gene product. A number of studies have shown that the *trpC* gene product is necessary for nodulation in the *B. japonicum* - soybean association. However, why the *trpC* gene is important in nodulation is unknown. IAA is involved in nodulation. Thus, by linking IAA biosynthesis to the *trpC* gene product, a link between *trpC* and nodulation has been established.

FUTURE PLANS: A collaborative study involving Dave Kuykendall, Jerry Cohen, Dave Ribnicky (all located in Beltsville) and myself is planned for early 1993. If succesfull the results of this study will be prepared for publication later in 1993.

USE OF 5-METHYLTRYPTOPHAN TO SELECT FOR *B. JAPONICUM* WITH ALTERED SYMBIOTIC PROPERTIES

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CRIS: 5402-12130-002-00D

PROBLEM: This investigation examined the effect of resistance to 5-methyltryptophan (5-MT), a toxic tryptophan analog, on the symbiotic properties of *B. japonicum*. In earlier studies, fourteen 5-MT resistant clones (MT-R) of *B. japonicum* were isolated from plates containing 5 g/l 5-MT and, as a control, thirteen clones (WT-C) were isolated from plates that contained no 5-MT. The symbiotic effectiveness of these MT-R and WT-C strains was tested on soybean. Greater variation in symbiotic effectiveness was observed with the MT-R clones than with the WT-C clones. Six MT-R strains fixed about 15 to 60% less, five were roughly equivalent and three MT-R strains fixed 20-64% more nitrogen than did the original wild-type parent strain (WT-P).

APPROACH: In CY-92 a follow-up control study was conducted in the greenhouse. This study involved fewer strains and more replications. Strains selected for this study included the four WT-C strains that performed best in the initial screening, the one that performed worst, and the WT-P.

FINDINGS: The results agreed with the initial study in that greater symbiotic variation was observed with the MT-R clones than with the WT-C clones. The four best MT-R strains again yielded plants with higher dry weights than the control WT-P strain. One strain was isolated that performed significantly better than the control. The results showed that a large percentage of *B. japonicum* strains with resistance to 5-MT have altered symbiotic properties. The procedure may offer a means of selecting for strains with improved symbiotic performance.

INTERPRETATION: Some *B. japonicum* mutants that are resistance to 5-methyltryptophan show improved nodulation. The procedure may provide a means of isolating inoculant bacteria with improved symbiotic properties.

FUTURE PLANS: The data obtained will be written up and submitted for publication in CY-93.

BIOREMEDIATION OF HIGH NITRATE WELL WATER BY VEGETABLE OIL INJECTION

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-00D

PROBLEM: Groundwater nitrate contamination is a potential health hazard. This project would evaluate a promising new method for removing nitrate from the groundwater. Innocuous oil would be injected into the aquifer around a well or would be used in an above ground sand-and-gravel filter. The oil would provide a carbon source for native microorganism and would stimulate these microorganisms to convert the nitrate to harmless nitrogen gas. Nitrate contamination of surface and subsurface waters is a major local, national and international problem. Nitrate in drinking water has been linked to methemoglobinemia in infants and cancer in adults and is thus a potential health threat in areas of high contamination. The maximum permissible level for drinking water in the USA has been set at 10 mg . The South Platte River Aquifer in northern Colorado, the study site for this project, is typical of many aquifers. Nitrate has leached from irrigated farmlands above the aquifer and has contaminated the local water supply. Only about 30% of the water from this aquifer meets the drinking water standard. In some areas water from this aquifer exceeds the maximum permissible NO_3^- N L^{-1} level by a factor of four. A timely solution is needed as several local communities have had to find new sources of water because of this groundwater problem. In some cases this has required the piping of water from outside of the immediate area, a difficult and expensive process. The development of economical methods of reducing the NO_3^- concentrations in groundwater is a high priority. The Soil-Plant-Nutrient Research Unit has both the personnel and equipment to carry out this study. Additionally, the research unit is located in northern Colorado near the South Platte River Aquifer and has many contacts within the area. Contacts include the Central Colorado Water Conservancy District, Colorado State University, the Northern Colorado Water Conservancy District, the Soil Conversation Service, the Environmental Protection Agency, and the U. S. Geological Survey.

The overall objective of this project is to test in the lab a promising new method for eliminating nitrate from groundwater. The method may be used as an *in situ* approach that utilizes the injection of innocuous vegetable oil around a well or the method may be used in above ground sand and gravel filters. With the *in situ* method vegetable oil would be injected at high pressure around the base of a well. Because oil is insoluble in water, it will form a plume of tiny droplets when it is injected under pressure into the water table. These droplets do not flow with the groundwater. Instead, because oil is less dense than water, the droplets tend to slowly rise toward the top of the water table. As the droplets rise some of them become trapped by the soil and form, in essence, a filter through which the groundwater flows. Microorganisms, capable of removing nitrate by denitrification, are naturally present in the vadose zone and water table. The absence of an appropriate carbon source normally limits the activity of these denitrifying microorganisms. The small droplets of vegetable oil would provide the needed carbon source, allowing the denitrifying organisms to actively utilize the nitrates presence in the groundwater as a term electron acceptor for

anaerobic respiration. The overall result of the process would be that the vegetable oil and nitrate would be converted to nitrogen gas, water, and carbon dioxide. And, most importantly, the nitrate content of the water flowing through this area would be reduced. Alternatively a sand-and-gravel filter may be used where the oil is injected into the inlet side of the filter.

APPROACH: The approach proposed here differs from earlier studies in two important aspects. First, the carbon source, a vegetable oil, would not dissolve in the water and thus will not move with the water. This allows the oil to remain in place and act as a filter through which the water moves. Second, the water is being treated only at the point from which it is removed from the aquifer. This is a much simpler and less expensive approach than attempting to treat the water as it enters an aquifer as other approaches have suggested. Two sets of studies are planned. These are batch laboratory studies and column laboratory studies. The batch studies will be performed first and will provide guidelines for the more complex column studies. Batch experiments will be done under static conditions in anaerobic laboratory containers. The major treatment variables will include soil type, amount of nitrate, amount of oil, and supplements added to the oil. Also, the degree of oil emulsification will be a variable. The major determinations to be made are the rate of denitrification and rate of oil decomposition. Preliminary studies show that vegetable oil is a good carbon source for denitrification. Flow columns will be set up to simulate the movement of aquifer water through soil layers containing dispersed vegetable oil. These studies will be based on the information gained from the previous batch studies and the conditions used with the flow columns will be those expected to yield optimum denitrification. During the study the water from the flow columns will be analyzed for nitrate and oil content and at the end of the study the columns will be destructively sampled for nitrate and oil content.

Samples will be taken from the South Platte river valley area in northern Colorado. This is an area where nitrate pollution is a major problem and an important concern to area communities. The South Platte river's shallow, alluvial aquifer is heavily contaminated with nitrate. Agricultural runoff from irrigation appears to be the source of the nitrate. Vadose zone material from immediately above (1 to 3 m) and, where possible, below (1 to 3 m) the saturated water table will be collected. Shallow samples, 3 to 6 meters below the soil surface, will be taken using a Giddings soil coring and sampling machine. Deeper samples, up to 76 m deep, will be taken with a truck mounted rotary drill rig. Both types of sampling equipment are available for use by the Soil-Plant-Nutrient Research Unit. Subsoil (C-horizon) material will also be collected for evaluation of microbial capacity for nitrate degradation. Considerable information is available on the soil types, their uses, and the nitrate content of the groundwater in the area.

FINDINGS: Two series of studies were conducted. One series looked at the effect the amount of vegetable oil has on denitrification. This study showed that vegetable oil does support denitrification, but that denitrification decreases as the amount of oil present increases. The results show that large amounts of oil (more than 4 mg per gram of support) were toxic to microbial population. Optimum denitrification occured at 1 mg of oil per gram os support. A second series of studies examined the rate of denitrification at the 1 mg of oil level. These studies show that only 48 to 72 hours are required for denitrifying

microorganisms to adapt to the vegetable oil as a sole carbon source. Soil extract, added at a 1% rate, was used as a source of microorganisms in these studies. Soil was taken from a shallow watertable 1.5 to 2 meters below the serface. These results also show that native denitrifying microorganisms can ready use vegetable oil as a carbon source.

INTERPRETATION: Proof of concept studies were initaited in the winter of 1992. The results from these studies demonstrated two important points. First, vegetable oil functions well as a sole carbon source for denitrification. Second, organisms native to the water table are present that are capable of carrying out denitrification using vegetable oil. It is not necessary to introduce specialized or adapted microorganisms. Thus prospects for the procedure look promising.

FUTURE PLANS: Two grant proposals have been submitted. One, "*In situ* bioremediation of high nitrate well water by vegetable oil injection", was submitted as a USDA/CSRS proposal and the other "Bioremediation of high nitrate well water by vegetable oil injection", as a Resource Conservation Act preproposal. We plan to proceed with research on this project in CY-93.

EFFECT OF HERBICIDES AND ANTAGONISTIC MICROORGANISMS ON CROP RESIDUE DECOMPOSITION

William J. Hunter
Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-00D

PROBLEM: Winter wheat-sorghum-fallow, wheat-corn-fallow, and winter wheat fallow crop rotations are prevalent in the Central Great Plains of the United States. In recent years, the use of minimum-tillage and no-till; where corn, sorghum or other crops are drilled into the existing wheat stubble; have become increasingly popular in these rotations. This procedure depends upon the use of herbicides to control weeds and upon the careful management of crop residues throughout the crop rotation. However, little information exists on the effect different herbicides have on the rate of residue decomposition. Recent reports by the Soil Conservation Service suggest that some herbicides, primarily paraquat, atrazine and glyphosate may accelerate the breakdown of crop residue. This issue is important in that a residue cover on the field protects the soil from erosion while increasing weed control, water infiltration, water conservation and crop yields. Also, the Conservation Compliance program in the 1990 Farm Bill requires a 30 percent residue cover in many individual farm conservation plans.

As with herbicides, little information is available on the effects antagonistic microorganisms may have on the decomposition rate of crop residue. In this part of the study, a commercial preparation called "Mycostop", based on an isolate of *Streptomyces griseoviridis*, was examined. "Mycostop" is a biofungicide that inhibits the growth of seed-borne and soil-bo-borne fungi and thereby protects plants from pathogenic fungi. Cellulolytic fungi are the maj or agents responsible for the decay of crop residue.

APPROACH: The effect "Mycostop", atrazine, glyphosate and paraquat have on the rate of wheat residue decomposition is currently being examined in laboratory studies. The basic procedure involves incubations of air dried wheat residue in laboratory containers under conditions of controlled temperature and moisture. At predetermined intervals, the biological activity of the microorganisms is assayed using carbon dioxide production as an indicator of the rate of decomposition. Weight loss of the treatments is also measured to determine the cumulative amount of decomposition at each time interval and the results are used to supplement data derived from the $CO2$ analysis.

FINDINGS: Data have been collected from experiments which were used to evaluate and improve the methodology for these studies. It has been determined that both $CO2$ analysis and weight loss measurements are effective indicators of crop residue decomposition. It has also been established that a sixteen week incubation period is optimal for these experiments. Investigations of the effects "Mycostop" and paraquat have on the rate of residue decomposition are currently in progress.

FUTURE PLANS: Investigation of the effects these factors have on residue decomposition will be a principal research focus in the future.

MAINTAIN QUALITY OF WATER AND THE ENVIRONMENT THROUGH IMPROVED NITROGEN USE EFFICIENCY

Gordon L. Hutchinson

CRIS: 5402-11000-004-00D
5402-11000-004-03S

PROBLEM: Gaseous N oxides, N_2O and NO_x ($NO+NO_2$), are radiatively, chemically, and ecologically important trace atmospheric constituents. N_2O absorbs outgoing planetary infrared radiation with wavelengths not removed by atmospheric CO_2 or H_2O, thereby contributing about 5% of the overall anthropogenic greenhouse effect. Because it is chemically inert in the troposphere, N_2O is readily transported to the stratosphere where it is also involved in destruction of the O_3 that protects life forms on Earth from incoming solar ultraviolet radiation. Conversely, NO_x has no direct effects on the planetary radiation balance, but is chemically very active. It plays a critical role in establishing the abundance of tropospheric oxidants, including O_3 (which is radiatively active) and OH radical (which is involved in the photochemical removal of atmospheric CH_4, another greenhouse gas with rapidly increasing concentration). Eventually, NO_x is itself photochemically oxidized to HNO_3, the fastest growing component of acidic deposition. Among other ecologically important functions of gaseous N oxides, the emission, transport, and subsequent redeposition of NO_x accomplishes substantial N redistribution both within and among natural and disturbed ecosystems. Because ecosystem primary productivity is often governed by N supply, this redistribution importantly influences the long term behavior of N-limited systems, including their potential for C sequestration. Microbial processes in soil is a major source of atmospheric N oxides and represents both a source and sink for atmospheric CH_4, so it is important to understand the exchange of these gases across the soil-atmosphere boundary and, if appropriate, to develop control technologies.

APPROACH: Short-term soil emission of gaseous N oxides has recently been measured from several different ecosystem types under a variety of soil and climatic conditions around the world. Conspicuously absent from the literature, however, are comprehensive longer-term studies that yield tenable estimates of total annual N_2O, and particularly NO_x, evolution from any particular site. Further extrapolating existing data to assess the overall contribution of soil N oxide emissions to the global atmospheric N_2O and NO_x budgets is also confounded by the apparent existence of multiple biotic and abiotic sources of the gases, each of which is subject to a different set of controllers. Because NO_x and N_2O are often produced by the same microbial processes, there may exist a relationship between their evolution rates from soil that would permit using the extensive database of N_2O emission measurements to forecast NO_x emissions at similar sites, but the paucity of simultaneous field measurements of the two gas emission rates precludes describing any such relationship. Recent data suggest that N transformations in soil also influence their CH_4 uptake rate, but the relative contributions of specific microbial processes remain to be determined. Overall objectives of my research are (1) to establish the magnitude and direction of annual soil and foliar gaseous NO_x exchange in a variety of agronomically- and environmentally-important situations, (2) to determine the

relation of NO_x to N_2O and CH_4 exchange rates in each situation, (3) to identify and characterize major controllers of the biotic and abiotic processes responsible for these exchanges, and (4) to assess the importance of the exchanges to crop productivity, to N use efficiency, to various environmental issues, and to the long-term behavior of natural and other low-N ecosystems. Procedures for laboratory soil incubation studies conducted to examine processes and pathways were summarized in a recent publication (Hutchinson and Andre, SSSAJ 53:1068-1074, 1989). Methods for field monitoring of NO_x, N_2O, and CH_4 exchange and for field testing of laboratory findings have been summarized in previous reports.

FINDINGS: The first full year's data was acquired from a comprehensive field study conducted in cooperation with personnel at the U.S. Central Great Plains Research Station on the Conservation Reserve Program conversion plots located there. Gaseous N oxide emissions were larger from fertilized than unfertilized plots and resulted primarily from the activity of nitrifying bacteria, rather than denitrifiers. A large fraction of gaseous N oxide loss occurred in a few brief intense bursts that followed fertilization or precipitation and especially a combination of these two. Like preliminary measurements made in 1991, soil emission of NO_x far exceeded that of N_2O, and soil management practices had substantial influence on N oxide evolution, with emission of both NO_x and N_2O varying in the order grass plots > no-till wheat plots > conventional tillage wheat plots. In contrast to 1991 results, short-term nitrifier activity measured in fresh soil samples was a poor predictor of gaseous N oxide emission rates, and each plot's NO_x emission rate did not covary with its CH_4 uptake rate. These differences emphasize the need for long-term field studies of soil trace gas exchange and for comprehensive modeling efforts to separate and characterize the multiple interactive controllers of trace gas production and transport.

Preliminary laboratory incubation experiments using soil from the field plots have established the minimum nitrification inhibitor concentration needed to separate nitrification-based from denitrification-based emissions, determined the minimum C addition needed to facilitate comparison of these two microbial processes, and demonstrated the suitability of our experimental setup for studying soil N oxide emissions as a function of N transformation dynamics. Ongoing studies of the effect of oxygen concentration on the relative contributions of nitrification and denitrification to soil N oxide emissions will help separate and identify the confounded influences of soil water content, oxygen concentration, and soil gas diffusion rates on production/consumption of NO_x and N_2O by various microbial groups in this soil.

In addition, this year marked the completion of review articles regarding chamber systems' use for measuring trace gas fluxes from soil, recent advances in our understanding of the biogeochemical controllers of NO_x and N_2O production, consumption, and transport in soil at both cellular and field/landscape scales, and a summary of several years study of gaseous N oxide emissions from managed subtropical grassland. Williams et al. (1992) was probably most significant of the four reviews because of its comprehensiveness and the interdisciplinary importance of its topic, and because it synthesized the complex biology of soil N oxide exchange into a form understandable by physical scientists and the tangled atmospheric chemistry of the gases in language available to biological scientists. Because of problems with the experimental results of co-authors of a joint manuscript listed as in preparation in last year's report, my data describing the humidity dependence of the efficiency of NO oxidation by CrO_3

(required for NO_x analysis using a luminol-based detector) were removed and will be submitted separately.

FUTURE PLANS: Because results from the field demonstrated the need for long-term measurement of soil trace gas exchange and for using simulation modeling to better understand net N oxide and CH_4 production and transport, we plan to continue efforts to (1) estimate total annual NO_x, N_2O, and CH_4 exchange from N-fertilized and unfertilized grass, no-till, and conventionally-tilled CRP plots at the Akron field station, (2) determine the relative contributions of nitrification, denitrification, and other processes (if they prove significant) to the measured exchange rates and (3) develop a process-level model that describes the contributions of each process to the measured exchange of NO_x, N_2O, and CH_4 in terms of easily-measured biological and geochemical parameters that have potential as predictors of the emission rates at other cultivated and grassland sites. Unlike existing models that attempt (with limited success) to account for the large variability in soil C and N exchange over short distance and time scales, the focus of our modeling effort will be to develop a simple equation that facilitates assessing the spatially and temporally integrated contributions of various ecosystem types, climatic regions, soil groups, and/or management schemes to regional- and global-scale budgets of the three gases by integrating soil, climate, and land use parameters in a way that reflects only the differences in annual emission rates among sampling sites. In addition I will (1) continue laboratory soil incubation studies to determine the effect of oxygen availability on the relative contributions of nitrification and denitrification to soil NO_x and N_2O exchange in accordance with the terms of Specific Cooperative Agreement No. 58-5402-1-102, (2) complete summarization and publication of the results from previous cooperative studies with Prairie View A&M University (funded by NASA and a USDA Specific Cooperative Agreement), (3) complete summarization and publication of cooperative studies with Dr. W.D. Guenzi conducted prior to his retirement, and (4) complete preparation of two additional invited book chapters, i.e., Hutchinson (1993) and Livingston and Hutchinson (1993).

MAINTAIN QUALITY OF WATER AND THE ENVIRONMENT THROUGH IMPROVED NITROGEN USE EFFICIENCY

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-00D

PROBLEM: Efficient use of N fertilizers is minimized in many agricultural systems because of the loss of large amounts of the applied N through nitrate leaching, by ammonia volatilization or by denitrification. As most fertilizers are applied to soil using ammonium salts or urea, limiting nitrification seems a mechanism to directly limit N losses from leaching and denitrification. A number of nitrification inhibitors have been used but all of them have serious limitations. The need remains to find a nitrification inhibitor that functions over a broad range of soils and soil conditions, both aerobic and flooded soils, that is easily prepared, is easy to use and is inexpensive. Dr. N.K. Banerjee, Indian Agricultural Research Institute, New Delhi, India, and I developed a nitrification inhibitor, coated calcium carbide (CCC) which is a slow release source of the potent nitrification inhibitor acetylene, which appears to have great potential. Since 1988 a number of researchers have been interested in the development of CCC and have worked with us to conduct field tests of the inhibitor. Field tests were conducted in dry seeded rice in Louisiana and New South Wales, Australia, in transplanted rice in several locations in India, in winter wheat in Victoria, Australia and Colorado, in corn in Nebraska, Colorado and China, and in cotton in northern New South Wales, Australia. In all instances CCC decreased the rate of nitrate formation during the cropping season, decreased measured denitrification and (by direct measurement or implication) decreased nitrate leaching (see publications). In several instances (transplanted and dry seeded rice and cotton) increased yields were measured when CCC was used. Unfortunately, the regulation of acetylene production with the CCC used in these experiments was not uniform or predictable enough under field conditions. The coating methods used did not provide a predictably uniform coating, so during some experiments acetylene was generated too rapidly and in others too slowly. We are still attempting to work with other scientists who may be able to provide improved coating techniques. Another potential problem in using CCC is the effect of continuous, long term exposure of soil microorganisms to acetylene.

APPROACH: In March, 1992 Dr. B.H. Byrnes of the International Fertilizer Development Center, Muscle Shoals, Alabama submitted a proposal to US-EPA to obtain funding to develop new coating procedures. He is still awaiting to hear if funding will be available. If he is able to work out new coating formulations the new material will be tested by Louisiana State University, Arkansas University and the International Rice Research Institute in the Philippines for use in dry seeded and transplanted rice. Other field studies, approaches described in earlier annual reports, will be initiated in irrigated corn and winter wheat in Colorado and Nebraska.

The project, begun in 1991 by Dr. Leif Klemedtsson and described in the 1991 Annual Report, to determine the effect of long term exposure of acetylene on nitrification, denitrification and microbial biomass was completed in mid 1992.

FINDINGS: A field study was initiated in 1991 to assess the effect of continuous acetylene exposure of soil on soil microbial processes. The first part of the experiment was to investigate long term effects of acetylene on nitrification and the second part was to study the recovery of

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the soil ecosystem from acetylene treatments. We found that after 1 to 3 months of continuous exposure of soil to acetylene that the soil microorganisms began to consume acetylene at high rates and that the consumption rates increased with length of soil exposure to acetylene. Nitrification rates decreased to a minimum of 21% of the control after three months but increased to 41% of the control after 11 months of exposure. One year after stopping acetylene additions to the soil, acetylene consumption rates were still much faster in the acetylene treated soils than in controls.

FUTURE PLANS: Continued tests of CCC depend upon the availability of new coating technology and production of improved coatings. No new field experiments will be initiated until the predictability of acetylene release is improved. If Dr. Byrnes is able to develop more effective coating procedures, then field studies will be conducted on the new product in a variety of crop and soil conditions. A manuscript describing the effect of long term exposure of acetylene to soil will be completed during the next few months.

New studies to determine the efficiency of polyolefin-coated ureas in spring barley and winter wheat will be initiated by Dr. Delgado during spring, 1993. Helena Chemical Company, Memphis, Tennessee has agreed to provide ^{15}N-labeled polyolefin-coated urea to conduct these studies.

ASSESS, PREDICT AND MITIGATE AGRICULTURAL C AND N TRACE GAS FLUXES THAT CONTRIBUTE TO GLOBAL CLIMATE CHANGE

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Soil-Plant-Nutrient Research Unit

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5402-11000-004-05S

PROBLEM: It is generally agreed that if present trends for the emission of greenhouse gases (CO_2, CH_4 and N_2O) from the earth's surface into the atmosphere continue, mean global temperature will rise two to six °C during the next century. Such a global atmosphere temperature increase would cause a rise in the ocean's water level, possibly change precipitation patterns, and alter agricultural production. According to discussions during an International Conference on "Soils and the Greenhouse Effect" the relative importance of agriculture and land use to the production of CO_2, CH_4, and N_2O were 30, 70, and 90%, respectively. A general recommendation from a number of International conferences is that intensive studies be made about conditions leading to the formation and escape of CO_2, CH_4, and N_2O in and from the soil, and their relative source/sink relationships in the soil, with the aim of creating the necessary scientific basis for improved land management practices to limit emissions or increase sinks while maintaining soil productivity.

APPROACH: A. A field program was begun in 1990 to monitor N_2O, CH_4 and CO_2 soil-atmosphere exchange from a variety of grassland agroecosystems over a 3 to 5 year period. See the 1990 annual report for methodology. In addition to flux measurements, a number of soil physical and chemical parameters are measured concomitantly. These monitoring programs have continued and have expanded to include other sites in the Great Plains. A study to assess the immediate and long term effect of plowing a grassland on gas fluxes was also initiated.

B. Field studies were conducted in dry seeded rice in Louisiana to assess the effect of nitrification inhibitors on CH_4 emissions from a flooded rice field.

C. Sites in Fairbanks, Alaska (Dr. Verlan Cochran) and on the West side of Puerto Rico near Lajas, Mayaguez and Isabela were established to expand the scope of soils and environmental conditions available for gas flux measurements. At each of two sites in Fairbanks and three sites in Puerto Rico 6 replicate plots were fertilized, after snow melt in Fairbanks and 4 times each year in Puerto Rico (simulating normal forage production operations) and 6 replicate plots were not fertilized. Within each treatment soil gas sampling and soil temperature probes were installed to monitor soil gas concentrations and temperature with depth down to 50 cm at most sites. Gas fluxes are measured, at least weekly, from each site. Soil and air temperatures, soil moisture content, and soil mineral N content are measured with each flux measurement. Nitrogen mineralization studies are made concurrently.

D. Field studies were conducted in an irrigated agricultural mountain meadow and in a subalpine meadow to broaden the scope of flux measurements.

E. Development of process level, regional models for CH_4 and N_2 flux are continuing. Drs. Bill Parton and Dennis Ojima, Natural Resource Ecology Laboratory, Colo. St. Univ. are conducting the modeling effort.

F. Measurements of CO_2, N_2O and CH_4 flux through alpine and subalpine snow packs in southern Wyoming were conducted during the winters of 1991 and 1992. Gas sampling devices were installed 15 cm into the soil, at the soil surface and at 20 to 50 cm intervals in the snowpack as the snow pack developed. Samples were collected an analyzed for the concentration of CO_2, N_2O and CH_4 by gas chromatography, from February through snow melt in May or June.

FINDINGS: A. The gas flux patterns that were shown early in the field flux studies continued through 1992. The data continue to show that N fertilization and cultivation of native soils decreases CH_4 uptake and increases N_2O emissions, thus contributing to increasing atmospheric concentration of CH_4 and N_2O. In newly plowed native grasslands both N_2O and CO_2 emissions increased immediately after plowing and N_2O emissions have remained high during the 5 months after plowing. Methane uptake in the recently plowed soils decreased immediately after plowing and has remained lower than undisturbed grasslands since that time.

B. Studies were conducted by Drs. C.W. Lindau and P.K. Bollich, Louisiana State University, concerning the effect of nitrification inhibitors and sulfate on CH_4 emissions from dry seeded, flooded rice. Methane emissions measured over the main rice cropping season were about 230, 260, 290, 310 and 360 kg CH_4 ha^{-1} in urea-fertilized soils treated with CCC, Na_2SO_4, $(NH_4)_2SO_4$, DCD, and urea control, respectively.

C. In Fairbanks, Alaska, Dr. Verlan Cochran initiated CH_4 and N_2O flux monitoring studies in two fertilized and unfertilized grassland sites, hill slope and flat meadow. Gas fluxes were monitored at least weekly from snow melt to resumption of snow cover. The data accumulated are currently being analyzed.

In Puerto Rico, three sites located within a distinct north-south evapotranspiration gradient, were established at the Puerto Rico Agricultural Experimental Station in Lajas on a vertisol, at the ARS Tropical Agricultural Research Station in Mayaguez on an ultisol, and at the ARS field station in Isabela on an oxisol. A post doctoral fellow, Dr. Jorge Delgado, has set up a laboratory at the ARS Tropical Agricultural Research Station in Mayaguez where most soil analyses and gas analyses are being performed. Dr. Delgado joined the Soil-Plant Nutrient Research Unit in Fort Collins in August, 1992. In August, 1992, Mrs. Margarita Licha was hired as a physical science technician to conduct the studies in Puerto Rico. The full set of field studies are progressing. The data accumulated during the last three months of 1992 are currently being analyzed.

D. Forage production in an irrigated mountain meadow in south central Wyoming was increased significantly by application of either urea or ammonium nitrate. Efficiency of spring applied N was greater than for fall applied N and rates of about 150 kg N/ha were optimal. Nitrous oxide emissions from urea application in the autumn were large following rainfall. In the spring N_2O emissions from

the ammonium nitrate plots were large after irrigation. Emissions from fall ammonium nitrate were higher than from either spring or fall urea fertilization. Methane flux was not appreciably affected by N-fertilization. Net emission of CH_4 occurred during flood irrigation and net consumption of atmospheric CH_4 was observed the remainder of the snow-free part of the year.

E. Evidence is accumulating that land use changes and other human activity during the past 100 to 200 years have contributed to decreased CH_4 oxidation in the soil. Recent studies have documented the effect of land use change on CH_4 oxidation in a variety of ecosystems. Increased N additions to temperate forest soils in the northeastern United States decreased CH_4 uptake by 30 to 60%, and increased N fertilization and conversion to cropland in temperate grasslands decreased CH_4 by 30 to 75%. Using these data we made a series of calculations to estimate the impact of land use and management changes which have altered the CH_4 soil sink in temperate forest and grassland ecosystems. These calculations indicate that the temperate zone soil sink for CH_4 would have increased by about 20 Tg y^{-1} during the past 150 y, assuming no loss of land cover to cropland conversion. The net effect of intensive land cover changes and extensive chronic disturbance to the temperate zone have resulted in about 30% reduction in the soil CH_4 sink.

F. Snow can cover between 44 and 53% of the land area of the northern hemisphere and may be meters deep in alpine and subalpine ecosystems for half or more of each year. Most trace gas budgets assume that trace gas exchange ceases when soil is snow covered or soil temperatures drop to near zero. Thus alpine and subalpine soils are generally considered net sinks for atmospheric CO_2 and of little concern for N_2O and CH_4 budgets. Our data suggest, however, that soil microorganisms beneath the snow continue to respire, produce N_2O, and consume CH_4 at near zero temperatures. Our studies show that the soils under alpine and subalpine snowpacks emit CO_2 and N_2O and take up atmospheric CH_4 throughout the snow covered period and these fluxes represent an important part of the annual budgets for these ecosystems.

FUTURE PLANS: A. The gas flux monitoring and mechanistic studies concerning CH_4 and N_2O will continue throughout 1993. A new study, conducted jointly with Dr. John Doran (ARS Lincoln, NE visiting scientist in Fort Collins) has been initiated at Sidney, NE, University of Nebraska Research Station, to assess the relationship of "soil quality" and trace gas fluxes in native grasslands and under different tillage treatments in wheat-fallow systems. The intensity of the efforts at Sidney depend upon the success of funding applications to NASA and DOE for joint projects with Colorado State University and Dr. Doran.

In 1981 a set of long term ^{15}N studies were initiated on sites where we are now monitoring trace gas fluxes. Dr. Delgado has initiated a study to trace the fate of the ^{15}N applied to the grassland 11 years earlier.

B. Field studies to asses the effect of CCC on CH_4 emissions from flooded rice will continue in Louisiana and be initiated at the International Rice Research Institute by Dr. Kevin Bronson if a suitable coating is developed.

C. Dr. Cochran will continue trace gas flux measurements at the sites in Fairbanks, Alâska during 1993. Ms. Licha and Dr. Delgado will continue the studies at the three sites in Puerto Rico. After the second year of data

collection from Alaska and a full year of data collection in Puerto Rico a synthesis of the information, comparing the data from Alaska, Colorado and Puerto Rico will be conducted.

D. Dr. Delgado began a ^{15}N use efficiency study with the fall fertilizer application on the irrigated mountain meadow. The spring fertilizer treatment will include ^{15} N addition to appropriate plots and gas flux measurements from these plots for a few weeks following fertilization. The ^{15}N treated plots will be harvested in August, 1993 at forage cutting time.

E. Efforts to develop a process level CH_4 oxidation model will continue and further modification of our process level N_2O model will continue as data from the diversity of sites where we are collecting flux data is available. Dr. Valentine is developing a model from which to use soil gas concentration data to calculate methane fluxes.

F. During the winter of 1992-93 Dr. Karl Zeller of the U.S. Forest service will be attempting to make CO_2 flux measurements using eddy correlation in one of the subalpine study sites. At the same time, Dr. Dick Sommerfeld (USFS) will analyze CO_2 concentration profiles in the snow pack. Calculations of area flux will be made by both methods and results will be compared. Throughout the snow covered period, soil gas profiles to 50 cm depth and snow gas concentration profiles will be measured.

G. Dr. Delgado will start a new study to determine if polyolefin-coated urea, a slow release source of fertilizer N, will decrease N_2 O emissions from urea-fertilized, irrigated spring barley and winter wheat fields.

MAINTAIN QUALITY OF WATER AND THE ENVIRONMENT THROUGH IMPROVED N-USE EFFICIENCY

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CRIS: 5402-12130-001-00D

PROBLEM: Major national concerns continues over the potentially harmful environmental impacts associated with excessive agricultural nitrate losses into groundwater. Agricultural production and concerns for sustainability and economic viability in the agricultural community are linked to fertilizer N-use. Various crop management systems (center pivot irrigated corn, and minimum-till rotations) are being rapidly adopted for Great Plain soils. The consequences of such practice on fertilizer and indigenous soil N-use efficiency and nitrate leaching are poorly understood.

I. Dryland Rotation System

APPROACH: A minimum-till wheat-sorghum-fallow rotation study at Akron, CO was established five years ago to determine: (1) NO_3 carryover and movement in profile, (2) the uptake or utilization of indigenous soil N and fertilizer N by the crops, (3) the movement of or release of N from crop residues, (4) the changes size and incorporation of fertilizer N into the microbial biomass. Our approach was to fertilize micro-plots at different time in the rotation with $^{15}NO_3$, transfer labeled residue to non-labeled plots, and seasonally measure N-uptake, N-transformations, nitrate distribution in the profile, and N-transfer into the biomass.

FINDINGS AND INTERPRETATION: Five years of sample collection have been completed. Chemical analyses have been complete on all but the 1992 crop. Soils were sampled to 150 cm in 30 cm intervals and analyzed for labeled N and nitrates. The tagged N indicated that most of the fertilizer N stayed within the to 60 cm of soil depth. The soil nitrate data indicated that the crops were a tremendous sink for nitrate.

Fertilizer N was applied in the fall of 1987 prior to planting winter wheat. Nitrate values in the spring of 1988 were upward of 70 ug NO_3-N/g soil whereas, only a few ug NO_3-N/g soil remained after the wheat crop. Tagged NO_3 was applied in the spring of 1989 to the sorghum crop and in the fall after harvest again only a few ug NO_3/g soil remained. After a year of fallow another wheat crop was grown without any further applications of fertilizer N. Analysis of that crop showed the prior fertilizer applications were having a great effect or interaction upon the amount of indigenous soil N assimilated by the crop.

FUTURE PLANS: The plan is to complete the total N and ^{15}N analyses for the 1992 crop and to move ahead with the statistical data analyses, interpretations and writing to complete this study.

II. Irrigation Studies

As mentioned in prior reports, efforts have been directed at publishing a 3 yr depleted ^{15}N-use efficiency, and nitrate leakage study. The first phase of the study was concerned with N-uptake by corn, nitrate carryover and nitrate leakage beneath the root zone as affected by adequate and excessive rates of fertilizer N and sprinkler irrigation water. The second phase of the study was concerned with the 5 yr recovery of residual soil nitrates by dryland cropping with winter wheat.

APPROACH: Fertilizer recommendation are generally made assuming that the plant uses the residual NO_3 in the 0-30 cm soil depth with the same efficiency as that in the 30-60 soil depth. In a cooperative experiment with Dale Westermann at Parma and Kimberly, Idaho this assumption was evaluated. Small amounts of $K^{15}NO_3$ were moved with different amounts of sprinkler irrigation water to either the 0-30 or 30-60 depth. Fertilizer N rates as NH_4NO_3 were surface broadcast and watered-in. Also depleted ^{15}N as $^{14}NH_4{}^{14}NO_3$ was applied in one treatment at the recommended rate. Irrigations were scheduled to minimize NO_3 movement and leaching. Recovery of the tagged NO_3-N was measured at various growth stages of spring wheat. Fertilizer N recovery at maximum grain yield was 48% at Kimberly, ID and 60% at Parma. Plant recovery of the $^{15}NO_3$-N from the 0-30 cm soil depth reached a maximum before flowering (Fleekes 10.5), whereas, uptake from the 30-60 cm soil depth increased to soft dough (Fleekes 11.2). Similar amount of $^{15}NO_3$-N were recovered from both soil depths within a location, 50% and 70% at Kimberly and Parma respectively. These data show that accurate N fertilizer recommendations need to account for residual NO_3 in the 0-60cm depth for spring wheat.

FINDINGS: A manuscript concerned with the three year corn study was completed peer reviewed and submitted to the SSSAJ. during the year. Journal reviews should be back shortly.

FUTURE PLANS: Writing is continuing on the wheat recovery of residual nitrates and hopefully a manuscript will soon be ready for peer review. All N and ^{15}N analyses have all been completed and statistical analyses and writing is needed.

ISOLATION, CHARACTERIZATION, AND GROWTH HABITS OF CELLULOLYTIC-N_2 FIXING MICROORGANISMS

Lynn K. Porter and William J. Hunter
Soil-Plant-Nutrient Research Unit

PROBLEM: Cellulose is the most abundant polysaccharide produced in nature with an annual production of about $0.75*10^{11}$ tons. Cellulose products are the major trash item entering U.S. municipal landfills. Current projections are that landfill tipping fees will soon exceed $100/ton and that the amounts of cellulosic wastes to be disposed of will rise to near $100*10^6$ tons/yr. It has long been thought that cellulose degradation occurred separately from biological N_2 fixation. However, recent discoveries raise the possibility that some cellulotytic-N_2 fixing microorganism might be widely distributed in nature. Depending upon their distribution and abundance such organisms could exert significant influence on the carbon and nitrogen cycling in various ecosystems. Moreover, if such organisms could be cultured in the right environments it is possible that cellulose wastes and residues could be turned into useful N products (N-rich mulches and animal feed) and thus provide another avenue for society to dispose of it wastes.

APPROACH: Mineral nutrient (minus N salts) plus cellulose are being used to culture cellulolytic microorganisms. Organisms that show strong growth will be isolated and cultured under different aeration conditions and tested to determine if they have the ability to reduce C_2H_2 to C_2H_4 or to fix $^{15}N_2$. Any organisms found that have the capacity to hydrolyze cellulose and fix dinitrogen will be further studied to determine the optimum nutritional and environment conditions needed for rapid growth.

FINDINGS: A major effort was made to find a Postdoctoral Research Associate. A good microbiologist who has some of the right skills was found and we are now in the process of getting him hired. Working with limited technician help we have started cellulose enrichment cultures devoid of N and have isolated about 27 organisms that grow on such media, six or seven of the organisms make fairly rapid growth. However, in preliminary tests none of these organisms have been able to reduce C_2H_2 even though they grow on the N free media.

FUTURE PLANS: Work will continue on collecting samples where cellulolytic organisms may exist and using cellulose enrichment cultures to isolate cellulolytic microorganisms. For organisms already isolated, testing of C_2H_2 reduction and $^{15}N_2$ fixation under differing environmental conditions will be carried out.

EFFICIENT USE OF FERTILIZER AND SOIL NITROGEN

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CRIS: 58-5402-12130-002-01S

PROBLEM: Means for improving N-use efficiency as well as preventing nitrate leaching and denitrification losses is needed. Encapsulated calcium carbide (ECC) inhibits nitrification which in turn prevents nitrate formation and leaching as well as reduces gaseous losses from denitrification. Limited information indicates that ECC may improve crop yields and possibly decrease methane emissions from soils, but additional studies are needed.

Isotopic ^{15}N is used to measure fertilizer N uptake, denitrification, and NO_3 leaching. However, one of the shortcomings of the isotopic method is the stimulating effect of the added ^{15}N compounds, especially ammonium salts, on the mineralization and uptake of indigenous soil N. The objectives of the projects are to (1) improve ^{15}N technology and the interpretation ^{15}N data, especially the 'added N interactions', (2) to determine the effects of ECC in preventing gaseous N and methane losses in various cropping systems.

APPROACH: Field tests were conducted in dry seeded, flooded rice in Crowley, LA, to determine the effect of ECC on methane emissions.

Nitrate and NH_4 recovery from soil extracts has been studied trying to use the Brooks, et al. (Soil Sci. Soc. Am J. 53:1707-1711, 1989) diffusion technique. This method uses cheap throw away medical urine sample containers and disks of GF/D filter paper treated with $KHSO_4$ mounted on stainless steel welding rods to trap volatilized ammonia.

FINDINGS AND INTERPRETATION: Acetylene slowly produced from ECC applied before flooding rice decreased methane emissions about 35%.

Numerous problems were encountered when trying to use the Brooks, et al. diffusion technique. The first problem is that the glass filter paper GF/D that they used melts in the Carlo Erba combustion column of the automated N analyzer (ANA). This problem can be overcome by using Whatmann #3 cellulose filter paper. The second problem is that the 6.4 mm (1/4") paper punch they used created a disk that is very difficult to get into the Sn combustion capsule of the ANA and when this disk is covered with dried $K^{15}NH_4SO_4$ salt it creates quite a problem. We solved this problem by switching to a 5 mm (3/16") paper punch and in order to maintain about the same surface area placed 2 disks on the stainless rod. The third problem was that the $KHSO_4$ used by Brooks et al. produced SO_2 in the ANA combustion an soon poisoned the Ag wool used to trap SO_2 and halides and then passed on to poison the Cu reduction column which reduces N_2O and NO compounds. We found that packing MnO_2 in the bottom of the combustion column oxidizes the SO_2 and stops the poisoning of the Cu. However, preliminary results replacing $KHSO_4$ with oxalic acid appears to be a better solution.

FUTURE PLANS: Additional work is needed on the diffusion technique with the oxalic acid traps. Manuscripts need to be prepared on uptake of ^{15}N in split root studies and for techniques developed for split roots studies and ammonia diffusion.

SOIL-PLANT-NUTRIENT RESEARCH UNIT

Publications

Aulakh, M.S., Doran, J.W. and Mosier, A.R. 1992. Soil Denitrification-Significance. Measurement and Effects of Management. In Advances in Soil Science. B.A. Stewart (ed.). Springer-Verlag. New York. pp. 2-57.

Bronson, K.F., Mosier, A.R. and Bishnoi, S.R. 1992. Nitrous oxide emissions from irrigated corn as affected by calcium carbide and nitrapyrin. Soil Sci. Soc. Am. J. 56:161-165.

Bronson, K.F. and Mosier, A.R. 1992. Suppression of methane oxidation in soils by nitrogen fertilizers, nitrification inhibitors, and urease inhibitors. Agron. Abst. 84:250.

Follett, R.F., Shaffer, M.J., Brodahl, M.K. and Reichman, G.A. 1992. NLEAP Simulation of Residual Soil Nitrate for Irrigated and Non-irrigated Corn. Agron. Abst. 84:277.

Follett, R.H., Follett, R.F. and Halvorson, A.D. 1992. Use of Chlorophyll meter to evaluate the N-status of dryland winter-wheat. Comm. in Soil Sc Sci. and Plant Anal. 23:687-697.

Follett, R.F. 1992. Fertilizer Related Pollution Issues for Managing Nutrients (Invited Keynote Paper). Vol. 1, pp. 227-243 IN M.S. Baswa, N.S. Pasricha, P.S. Sidha, M.R. Chaudhary, D.K. Benbi, and V. Beri. (eds.). Proceedings of the International Symposium on Nutrient Management for Sustained Productivity (Feb. 10-12). Punjab University Press. Ludhiana, India.

Freney, J.R., Smith, C.J. and Mosier, A.R. 1992. Effect of a new nitrification inhibitor (wax coated calcium carbide) on transformations and recovery of fertilizer nitrogen by irrigated wheat. Fert. Res. 32:1-12.

Hunter, W.J. 1992. Production of the plant hormone ethylene by soybean roots and nodules. Abstracts of the Annual Meeting of the American Society for Microbiology. p. 307.

Hunter, W.J. 1992. The effect of etherol on nodulation by *Bradyrhizobium japonicum*. Abstract #76, Sixth international symposium on molecular plant-microbe interactions.

Hunter, W.J. and Kuykendall, L.D. 1992. The Symbiotic Properties of 5-Methyltryptophan Resistant Mutants of *Bradyrhizobium japonicum*. Abstract #834 in the 9th International Congress on Nitrogen Fixation, Program and Abstracts.

Hutchinson, G.L., Beard, W.E., Vigil, M.F. and Halvorson, A.D. 1992. NO and N_2O emissions from perennial grass and winter wheat in the semiarid Great Plains. Agron. Abstr. p. 260.

Hutchinson, G.L. and Brams, E.A. 1992. NO versus N_2O emissions from an NH_4^+-amended Bermuda grass pasture. J. Geophys. Res. 97:9889-9896.

Hutchinson, G.L. and Davidson, E.A. 1993. Processes for production and consumption of gaseous nitrogen oxides in soil, pp. 79-93. IN: L.A. Harper, A.R. Mosier, J.M. Duxbury, and D.E. Rolston (eds.) Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Spec. Publ. 55, Madison, WI.

Hutchinson, G.L., Guenzi, W.D. and Livingston, G.P. 1993. Soil water controls on aerobic soil emission of gaseous N oxides. Soil Biol. Biochem. 25:1-9.

Hutchinson, G.L. and Livingston, G.P. 1993. Use of chamber systems to measure trace gas fluxes, pp. 63-78. IN: L.A. Harper, A.R. Mosier, J.M. Duxbury, and D.E. Rolston (eds.) Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Spec. Publ. 55, Madison, WI.

Kuykendall, L.D., Hahn, M., Hennecke, H. and Hunter W.J. 1992. Genetically improved rhizobia and their use in agriculture. p. 211 - 218. In K. Mulongoy, M. Gueye and D.S.C. Spencer (eds.) Biological Nitrogen Fixation and Sustainability of Tropical Agriculture. John Wiley and Sons, London. 488 pp.

Kuykendall, L.D. and Hunter, W.J. 1992. Altered tryptophan biosynthesis in *Bradyrhizobium japonicum* gives enhanced nodulation and nitrogen fixation. p. 71-79 In Gresshoff, P. M. (ed.) Plant biotechnology and development. CRC press, Ann Arbor, MI. 171 pp.

Kuykendall, L.D. and Hunter, W.J. 1992. Characterization of new *Bradyrhizobium japonicum* tryptophan auxotrophs produced by marker exchange mutagenesis. Abstract #535 in the 9th International Congress on Nitrogen Fixation, Program and Abstracts.

Kuykendall, L.D. and Hunter, W.J. 1992. Marker exchange deletion mutagenesis of the *trpCD* region of *Bradyrhizobium japonicum*. Abstract #90, Sixth international symposium on molecular plant-microbe interactions. Seattle, Washington.

Mosier, A.R. and Schimel, D.S. 1992. Nitrification and Denitrification. In Isotopic Techniques in Plant, Soil, and Aquatic Biology. R. Knowles and H. Blackburn (eds.). Academic Press Inc., New York. pp. 181-208.

Mosier, A.R., Bronson, K.F., Freney, J.R. and Keerthisinghe, D.G. 1992. Inhibition of N_2O emission from fertilized soils. Proceedings of CH_4 and N_2O Emission from Natural and Anthropogenic Sources and the Reduction Research Plan Workshop. Tsukuba, Japan. pp. 135-149.

Mosier, A.R., Follett, R.H., Klemedtsson, L.K. and Follett, R.F. 1992. Methane and nitrous oxide flux in an irrigated, N-fertilized mountain meadow. Agron. Abst. 84:263.

O'Deen, W.A. and Follett, R.F. 1992. Ammonia emission from soybean amended soil with various soil temperature and moisture levels. Agron. J. 5:893-896.

Porter, L. K. 1992. Depleted ^{15}N study of nitrate carryover and leaching and N recovery by corn as affected by three years of various fertilizer N and irrigation levels. Agron. Abstr. p. 288.

Porter, L. K. and A. R. Mosier. 1992. ^{15}N Techniques and Analytical Procedures: Indo/U.S. Science and Technology Initiative. U.S. Department of Agriculture, Agricultural Research Service, ARS-95, 26pp.

Porter, L. K. 1992. Ethylene inhibition of ammonium oxidation in soil. Soil Sci. Soc. Am. J. 56:102-105.

Ronaghi, A., Soltanpour, P.N. and Mosier, A.R. 1992. Nitrapyrin effect on nitrate leaching and N-15 uptake efficiency in corn. Agron. Abst. 84:290.

Shaffer, M.J., Wylie, B.K., Follett, R.F. and Bartling, P.N.S. 1992. Using climate/weather data with the NLEAP model to manage soil fertility and nitrate leaching. Agron. Abst. 84:23.

Van Cleemput, O., Mosier, A.R., Patrick, W.H., Jr., Smith, K. and Wassmann, R. 1992. Methane and nitrous oxide flux measurements from soil and plant systems. In Manual on Measurement of Methane and Nitrous Oxide Emissions from Agriculture. J.D. Dargie and C. Hera (eds.). IAEA-TECDOC-674. International Atomic Energy Agency. Vienna. pp. 45-84.

Vigil, M.F., Power, J.F., Schepers, J.S., Francis, D.D. and Mosier, A.R. 1992. Nitrogen recovery of irrigated corn fertilized with large urea pellets placed with nitrification inhibitors. Agron. Abst. 84:360.

Vigil, M.F., Power, J.F., Schepers, J.S., Francis, D.D. and Mosier, A.R. 1992. The effect of large urea pellets placed with DCD and acetylene on nitrogen recovery and soil inorganic N dynamics of irrigated corn. Soil and Water Conservation Society (Abstract).

Waggoner, P.J. (Chr), Baldwin, L., Crosson, P., Duvick, D., Drabenstott, M., Follett, R.F., Jensen, M.E., Marland, G., Peart, R., Rosenberg, N. and Ruttan, V. 1992. Preparing U.S. Agriculture for Global Climate Change. Council for Agricultural Science and Technology (CAST). Report 119. Ames, IA. 96p.

Weier, K.L., Doran, J.W., Mosier, A.R. and Peterson, T.A. 1992. Potential for bioremediation of high nitrate groundwater via denitrification. Agron. Abst. 84:341.

Westermann, D.T., Brown, B.D. and Porter, L.K. 1992. Recovery of NO_3-N from two soil depths by irrigated spring wheat. Agron. Abst. p. 295.

Williams, E.J., Hutchinson, G.L. and Fehsenfeld, F.C. 1992. NO_x and N_2O emissions from soil. Global Biogeochem. Cycles 6:351-388.

SUGARBEET RESEARCH UNIT

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MISSION STATEMENT

Utilize distinctive site environmental and disease-free characteristics and specifically developed team expertise to: develop new knowledge and adapt biotechnologies to modify host-pathogen relations that affect disease resistance, pathogenesis, and epidemiology in sugarbeet and other plant species pertinent to sugarbeet cultivation; discover new information and techniques to identify and produce genotypes exhibiting superior disease and stress tolerance and agronomic qualities; and provide new knowledge that improves production efficiency and biochemical processing characteristics of sugarbeet.

VARIETAL SUSCEPTIBILITY OF NEMATODE TRAP CROPS TO *RHIZOCTONIA SOLANI* FROM SUGARBEET - SECOND TRIAL

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: The two nematicides currently used to suppress the beet cyst nematode, *Heterodera schachtii*, soon may be banned nationwide for use on sugarbeet. Indeed, they already have been banned in California, and one has been banned in Wisconsin because of contaminated ground water. Thus, sugarbeet growers and the industry have shown great interest in oil mustard (*Sinapis alba*), forage radish (*Raphanus sativus*), and buckwheat (*Fagopyrum esculentum*), which have been used extensively in Europe as trap crops for the beet cyst nematode. In an earlier study with only two mustard cultivars and one radish cultivar, the test species were highly susceptible to two strains of *Rhizoctonia solani* from sugarbeet, the cause of seedling damping-off and root rot in sugarbeet. Use of these crops in areas where Rhizoctonia diseases are endemic many necessitate the development of genetic resistance to the fungus, but additional cultivars and species must be screened to select the best cultivars for germ plasm enhancement. In my 1991 report, data on the susceptibility of seven radish, four mustard, and two buckwheat cultivars to the two strains of *R. solani* were presented. Results of a second confirmatory trial is reported herein.

APPROACH: Trial 2 was identical to trial 1. Seven radish, four mustard, and two buckwheat cultivars were planted in steam-pasteurized soil infested with 0.5 propagules per gram soil of either strain R-6 or R-9 of *R. solani*. A randomized complete block design was used, with five replicates and 40 seeds per cultivar per replicate. Controls were seed of each cultivar and sugarbeet planted in noninfested soil. Damping-off as a percentage of control survival was recorded 21 days postplanting.

FINDINGS: Similar to trial 1, both strains of *R. solani* induced significant seedling death in radish and mustard cultivars and, to a lesser extent, in the buckwheat cultivars (Table 1). Generally, strain R-9 was more virulent in radish cultivars than R-6, with the exception of 'Fortissimo.' The same was true for the buckwheat cultivars. In the mustards and sugarbeet, strain R-6 induced more damping-off than strain R-9. A great deal of variability in susceptibility was observed among and within the test cultivars.

INTERPRETATION: As in 1991, the fungal strain X cultivar and fungal strain X trap-crop species interactions would necessitate either independent breeding programs for resistance, or the use of inoculum of both strains in selection programs. However, damping-off strains (e.g., R-6) do not induce root rot of older beets and, thus, can be controlled effectively with available seed-treatment fungicides. The considerable variability in susceptibility among and within the trap-crop species should enable breeders to increase resistance levels to root-rot strains (e.g., R-9) by initial mass selection techniques.

FUTURE PLANS: Cultivars in these trials that showed the highest levels of resistance will be used for initial mass selections for resistance.

Table 1. Damping-off of cyst nematode trap crops planted in soil infested with two strains of *Rhizoctonia solani* (R-6 & R-9) as a percentage of control survival in noninfested soil; means of five replicates

Cultivar	Type	% Damping-off	
		R-6	R-9
Pegletta	Radish	58	79
Nemex	Radish	65	89
Siletina	Radish	31	71
Adagio	Radish	63	84
Siletta Nova	Radish	48	58
Salubre	Radish	62	73
Fortissimo	Radish	60	40
Metex	Mustard	65	60
Maxi	Mustard	90	86
3-9001	Mustard	79	45
3-9002	Mustard	68	23
Prego	Buckwheat	16	66
Tardo	Buckwheat	8	49
MonoHy D-2	Sugarbeet	94	93

SURVIVAL OF *RHIZOCTONIA* IN ORGANIC RESIDUES IN SOIL FOLLOWING TRAP-CROP GROWTH

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CRIS: 5402-21220-002-00D

PROBLEM: The soilborne fungus *Rhizoctonia solani* persists as a saprophyte in colonized organic residues in soil, with survival durations dependent upon the type and amount of organic matter, soil microbes, the soil environment, and climate. Because mustard (*Sinapis alba*) and radish (*Raphanus sativus*) have been shown in our lab to be susceptible to root-rot and damping-off isolates of *R. solani* from sugarbeet, and sugarbeet growers have interest in these species as trap crops for the beet cyst nematode, information is needed on survival of the fungus in infected and noninfected root material of these crops.

APPROACH: Three mustard cultivars, one radish variety, and sugarbeet were grown for 60 days in soil infested with *R. solani* isolate R-6 (damping-off strain) or R-9 (root-rot strain) from sugarbeet, each at a population density of 0.5 progagules per gram soil. Surviving plants were removed from the pots, and the pots of soil were kept from drying out completely until they were replanted with sugarbeet at 30, 60, and 120 days after the initial 60-day growth of the trap crops. Percent damping-off 21 days after planting sugarbeet was used as a measure of pathogen survival in the soil. A randomized block design was used, with five replicates in each of two trials.

FINDINGS: Both isolates of *R. solani* survived in the soil organic residues of the trap crops for at least 4 months, as shown by the high percentages of sugarbeet damping-off (Table 1). Seedling death induced by R-6 remained relatively constant over the 30- and 60-day plantings, with a slight decrease after the 120-day planting. There was a slight increase in damping-off induced by isolate R-9 between 30 and 60 days, followed by a decrease in the 120-day planting. With either isolate, there was no significant time X cultivar interaction, but the difference between isolates was significant. Differences among cultivars within isolate groups were not significant. Isolate R-6 induced more damping-off than isolate R-9 in all test cultivars.

INTERPRETATION: *R. solani*, under the relatively constant conditions of the greenhouse, could survive in trap-crop residues for at least 4 months and induce severe seedling disease in subsequent plantings of sugarbeet.

FUTURE PLANS: Survival of the pathogen in trap-crop residues will be tested under various environmental conditions, particularly soil temperature.

Table 1. Percent damping-off induced by isolates R-6 and R-9 of *Rhizoctonia solani* in sugarbeet planted 30, 60, and 120 days following harvest of mustard and radish trap crops, which had been grown for 60 days in pasteurized soil infested with either pathogen

Cultivar[1]	Postharvest planting[2]	% Damping-off R-6	% Damping-off R-9
3-9001	30	96	67
	60	96	68
	120	88	56
3-9002	30	98	54
	60	90	68
	120	86	66
Nemex	30	90	61
	60	93	73
	120	81	68
MonoHy D-2	30	98	76
	60	98	78
	120	90	63

[1] 3-9001 and 3-9002 = mustard (*Sinapis alba*); Nemex = radish (*Raphanus sativus*); MonoHy D-2 = sugarbeet.

[2] Following 60 days of growth of test cultivars, sugarbeet was planted after a fallow period of 30, 60, 120 days. Percent damping off in sugarbeet was recorded 21 days post-planting.

POTENTIAL OF *STREPTOMYCES GRISEOVIRIDIS* FOR SUPPRESSION OF SUGARBEET DAMPING-OFF IN SOIL INFESTED WITH *FUSARIUM* SPECIES

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CRIS: 5402-21220-002-00D

PROBLEM: *Fusarium* spp. induce significant seedling stand losses in sugarbeet and also attack older beets, causing a disease complex called Fusarium yellows. Seed-treatment or soil-applied fungicides are ineffective against these pathogens, and only a few commercial lines of sugarbeet have shown a modicum of resistance to these fungi. Thus, biological control would offer a safer, more natural means of suppressing *Fusarium* spp. The bacterium *Streptomyces griseoviridis* significantly inhibited sugarbeet pathogens *F. avenaceum* and *F. oxysporum* in vitro (NRRC 1991 Report, pp. 177-178). However, nothing is known about the agent's ability to suppress disease in soil culture.

APPROACH: A dehydrated, commercial preparation of *S. griseoviridis* was rehydrated to make a 0.1% (w/v) suspension. This suspension was used for three recommended treatments: a spray on the soil surface at planting (SS-P), a spray on the soil surface at planting coupled with seed treatment (ST) with the dehydrated agent (ST/SS-P), and a spray at planting and again at 14 days after planting (2S-P&14). For the seed treatment, the agent was applied at a rate of 8 mg/g seed by agitating the dehydrated agent and seed in a mason jar. Untreated seed of sugarbeet cultivar MonoHy D-2 was surface-disinfested for 3 min in 0.5% sodium hypochloride, rinsed three times in sterile distilled water, then blotted dry before seed treatment with the agent or planting. Sand-oatmeal cultures of *F. avenaceum* and *F. oxysporum* were used to infest the soil of inoculated treatments. A randomized complete block design was used with four replicates. Percent damping-off, as a percentage of nontreated control survival, was recorded 28 days postplanting.

FINDINGS: *S. griseoviridis* was ineffective in suppressing Fusarium damping-off in sugarbeet regardless of application treatment. Percent damping-off induced by *F. avenaceum* ranged from 92-99%; *F. oxysporum* induced 93-100% seedling death.

INTERPRETATION: The bacterial agent apparently is an inefficient colonizer of the sugarbeet root rhizosphere/rhizoplane, and the *Fusarium* spp. were able to rapidly attack juvenile root tissue before any inhibitory effect of the agent was possible. *S. griseoviridis* is not a mycoparasite, but produces an "inhibitory factor" in advance of its growth. Conceivably, normal irrigations of potted plants diluted the inhibitory substance to the point of ineffectiveness. If methods could be devised to enhance the establishment of a large soil population density of the bacterium in the field during fallow periods, an effective control of Fusarium yellows might be realized. Currently, however, *S. griseoviridis* does not offer an effective means of suppressing Fusarium diseases in sugarbeet.

FUTURE PLANS: Research on the use of this bacterium for biocontrol of *Fusarium* spp. will be terminated.

POTENTIAL OF *STREPTOMYCES GRISEOVIRIDIS* FOR SUPPRESSION OF RHIZOCTONIA DAMPING-OFF IN SUGARBEET

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: *Rhizoctonia solani* is the causal agent of seedling damping-off and root rot of older sugarbeets, causing significant yield losses wherever the crop is grown. Although some fungicide seed treatments are effective in suppressing damping-off, there are no chemicals registered for suppressing the more serious root rot strains of the pathogen. The deleterious effects of pesticides on the environment and their possible withdrawal from the market make biological control an attractive alternative. The bacterium *Streptomyces griseoviridis* significantly inhibited growth of two strains of *R. solani* in vitro (NRRC 1991 Report, pp. 177-178), but nothing is known about the agent's ability to suppress the fungus in soil culture of sugarbeet.

APPROACH: A dehydrated, commercial preparation of *S. griseoviridis* was rehydrated to make a 0.1% (w/v) suspension. For treatments with this agent, pots of soil were irrigated with 100 ml of the suspension, then incubated for 72 hr before introduction of *Rhizoctonia* or other amendments. Colonized, ground barley-grain was used to infest soil with a root-rotting strain (R-9) of *R. solani*. Steam-pasteurized soil was used in all pots. Treatments were: (1) *S. griseoviridis* alone; (2) sterile, ground barley grain plus *S. griseoviridis*; (3) sterile, ground barley grain alone; (4) *S. griseoviridis* plus isolate R-9; (5) isolate R-9 alone; and (6) nontreated control. Commercial sugarbeet cultivar MonoHy D-2 was planted in all pots; seedling survival was recorded 21 days postplanting, and the percent decreases in survival from the nontreated control were calculated. The final soil population density of *R. solani* was determined for treatments 4 and 5. A randomized complete block design was used with five replicates in each of two trials; means of the two trials are presented.

FINDINGS: The bacterium had little effect on seedling survival (Table 1). Isolate R-9 decreased survival by 61%, whereas a 55% decrease was realized when R-9 and the bacterium were used in concert. The difference of 6% between these two treatments could have been due solely to the effect of the barley and agent themselves (see treatment 2). Final soil population densities of *R. solani* for treatments 4 (1.3 propagules/g) and 5 (1.9 propagules/g) were not significantly different.

INTERPRETATION: *S. griseoviridis* was ineffective in suppressing seedling damping-off of sugarbeet induced by *R. solani*. Because the bacterium produces an "inhibitory factor" in advance of its growth (NRRC 1991 Report, pp. 177-178), normal irrigations applied to the pot cultures may have diluted the "factor" beyond effectiveness.

FUTURE PLANS: The physical properties of the "inhibitory factor" produced by *S. griseoviridis* will be studied, especially heat lability and solubility in water

and organic solvents, preliminary to attempts at biochemical identification of the factor. Because the bacterium has not been reported from the U.S., approval to conduct research is limited to greenhouse and laboratory facilities.

Table 1. Decrease in sugarbeet seedling survival as a percentage of control survival 21 days after soil amendment with *Streptomyces griseoviridis*, sterile ground barley, *Rhizoctonia solani*, or combinations of amendments

Amendment	% Decrease in seedling survival
1 *S. griseoviridis* (Sg)[1]	3
2 Sterile barley (ST)[2] + Sg	5
3 ST[2]	6
4 *R. solani*[3] + Sg[1]	55
5 *R. solani*[3]	61

[1]100 ml of a 0.1% (w/v) suspension per 10-cm-diameter pot of soil applied 72 hr preplant.

[2]Soil concentration of sterile barley grain was adjusted to that of colonized grain added for treatments 4 and 5.

[3]Applied as colonized, ground barley grain at a rate of 0.5 propagules of fungus per gram soil.

GERMPLASM DEVELOPMENTS FOR RESISTANCE TO SUGARBEET DISEASES

L. W. Panella, E. G. Ruppel, and R. J. Hecker (retired)
Sugarbeet Research Unit

CRIS: 5402-21220-002-OOD

PROBLEM: *Rhizoctonia solani* and *Cercospora beticola* are two fungi that may produce a severe reduction of yield in many sugarbeet production areas. Cultural control measures are not adequate by themselves, and often no chemicals are registered for control of these diseases, or chemical control is expensive and/or is environmentally unsafe. Increased levels of genetic resistance are needed to minimize growers' losses from these diseases.

APPROACH: Genetic information developed previously in our research was used to execute additional cycles of pathogen inoculation, plant selection, and recombination among germplasm that we have in our cyclic improvement program. Germplasms in various stages of improvement were evaluated for resistance in inoculated field tests. Results of these tests were the basis of decisions about specific germplasm, i.e., retain, shelve, discard, recombine, release, register, etc. Germplasms likely to be useful for variety improvement were identified and released for use by other sugarbeet breeders.

FINDINGS: The germplasm described below was released in 1992. FC404CMS and FC404 were released because they are an annual, monogerm, CMS and O-type maintainer, respectively. They are intended for utilization by breeders and scientists to expedite generation advancement of specific hybridizations and for other research purposes. FC715 and FC715CMS were released because of their resistance to root-rotting strains of *R. solani* and for their potential use on the female side of Rhizoctonia-resistant hybrids. Each of the lines, FC716, FC717, FC718, and FC719, has been developed from genetically different and unique sources. They were released because of their resistance to root-rotting strains of *R. solani*. Breeder seed will be maintained by ARS, and will be provided in quantities sufficient for reproduction upon written request.

The following materials are currently under development. Five lines are attempts to combine resistance to *R. solani* and the curly top virus for use by breeders to develop hybrids in areas where both of these diseases are a problem. Three lines are attempts to combine resistance to *R. solani* and Cercospora leaf spot for use by breeders to develop hybrids in areas where both of these diseases are a problem. Two lines are attempts to combine resistance to *R. solani* and commercial sucrose quality. They are intended for use by breeders to develop commercially acceptable hybrid parents with resistance to Rhizoctonia root rot. Two lines are attempts to attain extremely high levels of resistance to *R. solani*. They are intended for use by breeders to develop lines with resistance to Rhizoctonia root rot. All are in various stages of development, with some possibly ready for release after disease screening in 1993.

Three lines, **FC709(4X)**, **FC710(4X)**, and **FC712(4X)**, are being converted to tetraploidy (4X) after treatment with colchicine. They are lines that were released from the Fort Collins program previously as diploids (2X) with high resistance to Rhizoctonia root rot and good combining ability.

FUTURE PLANS: The lines under development will be tested and released as appropriate. In our germplasm enhancement program, we will continue to combine resistance to *R. solani* with resistance to other important sugarbeet pathogens, with attention to maintaining a genetic background of high commercial quality for use by industry and other sugarbeet breeders.

ISOFLAVONOID PHYTOALEXINS IN *Beta maritima*

Susan S. Martin
Sugarbeet Research Unit

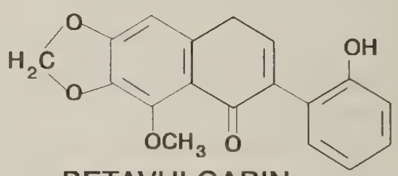
CRIS: 5402-21220-002-00D

PROBLEM: In previous work, I found that many diverse genotypes of *Beta vulgaris*, the broad species including sugarbeet, table beet, chard, and fodder beet, all accumulated the flavonoid phytoalexin betavulgarin (BV) when infected by the leaf-spotting fungus *Cercospora beticola*. Like other phytoalexins, this compound may be involved in the plant's disease resistance response. The ability of other taxa within the genus *Beta* to accumulate this compound in response to fungal elicitation is of interest in relationship to their disease resistance and potential as genetic sources of resistance for incorporation into sugarbeet.

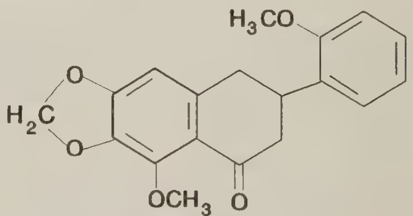
APPROACH: An on-going evaluation of *C. beticola* resistance in *Beta* lines from the germplasm collection of the USDA-ARS North Central Plant Introduction Station at Ames, IA, provided an opportunity to sample 23 diverse lines of *B. vulgaris* L. ssp. *maritima* (L.) Thell. under disease conditions. The tested lines originated from diverse habitats, collected from Greece and the Grecian Islands, Italy, and the British Isles. Lesioned leaves from infected plants were extracted and analyzed by high performance liquid chromatography for their content of BV and related flavonoid compounds.

FINDINGS: Every line of *B. vulgaris* ssp. *maritima* accumulated BV (Fig. 1) under *C. beticola* infection. The flavanone betagarin (Fig. 1) sometimes accompanied BV, and several unidentified flavonoids also were present in some samples.

INTERPRETATION: The steps in the human-mediated derivation of sugarbeet from ancestral beet types are unknown, but the sea beet, *B. vulgaris* ssp. *maritima*, is a likely ancestral form. These Mediterranean ancestors of the cultivated beet types must have had a long coevolutionary association with *C. beticola*, which is found everywhere beets occur. Thus, sources of disease resistance or tolerance may exist within genepools of the seabeet taxon. The presence of BV in all tested populations is consistent with its probable involvement in resistance to Cercospora leaf spot disease. These findings also contrast with a literature report (Richardson, P. M. 1981. Biochem. Syst. Ecol. 9:105-107) that BV was not accumulated in response to the non-pathogenic fungus *Helminthosporium carbonum*.



BETAVULGARIN
2'-hydroxy-5-methoxy-6,7-methylenedioxyisoflavone



BETAGARIN
5,2'-dimethoxy-6,7-methylenedioxyflavanone

Figure 2. Structures.

FUTURE PLANS: Testing of other *Beta* taxa for BV accumulation under Cercospora leaf spot infection will be continued as possible. Certain tested lines of *B. vulgaris* ssp. *maritima* contained significant amounts of flavonoid compounds other than betavulgarin and betagarin, known sugarbeet phytoalexins. Such lines would be good sources for isolation of these compounds to determine their effectiveness as anti-fungal agents, or their possible involvement in biosynthetic pathways to active compounds. Although work of this type is not planned in the next year, it may be pursued in the future.

ASSESSING QUALITY OF DECOMPOSING SUGARBEETS IN FACTORY STORAGE PILES

Susan S. Martin
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: When grown in cold-winter areas such as the Great Plains, sugarbeets must be harvested before the ground freezes. Beets are transported from harvest sites to a processing factory where they are stored, usually in huge, open piles, until they can be processed. In Colorado/Nebraska/Wyoming, harvest typically occurs from late September to early November, and pile-stored beets are processed until March or April. Pile storage is most satisfactory when an early cold temperature period freezes the pile solidly, and when beets remain frozen until they are processed. If early storage conditions are not conducive to freezing, or if lengthy warm periods subsequent to freezing allow areas of the piled beets to thaw, sites of injury suffered during harvest and transport quickly undergo microbial attack and entire pile areas decompose. The winter of 1991-92 was such a period, and many sections of beet piles decomposed to the point that factory personnel judged large quantities of beets unprofitable to process. However, there existed no certainty that the processing quality of beets was correctly judged from their their visual appearance. If a visual assessment were incorrect, many thousands of dollars might be wasted in a futile attempt to process beets with little recoverable sucrose, or, alternatively, by the discarding of processable beets.

APPROACH: In collaboration with Dr. Larry E. Gholson of The Western Sugar Company, beet samples at various visual stages of decomposition were obtained from storage piles at three sugar processing factories (CO, NE, WY/MT). Factory personnel at each site classified each 3-beet sample into a visual quality class, photographed the sample, and analyzed it for sucrose by standard polarimetric techniques. Frozen aliquots of the same extracts used for polarimetry were transported to our laboratory for detailed analysis of sucrose and other sugars (the monosaccharides glucose and fructose, the trisaccharide raffinose). All of the non-sucrose sugars are detrimental to processing quality.

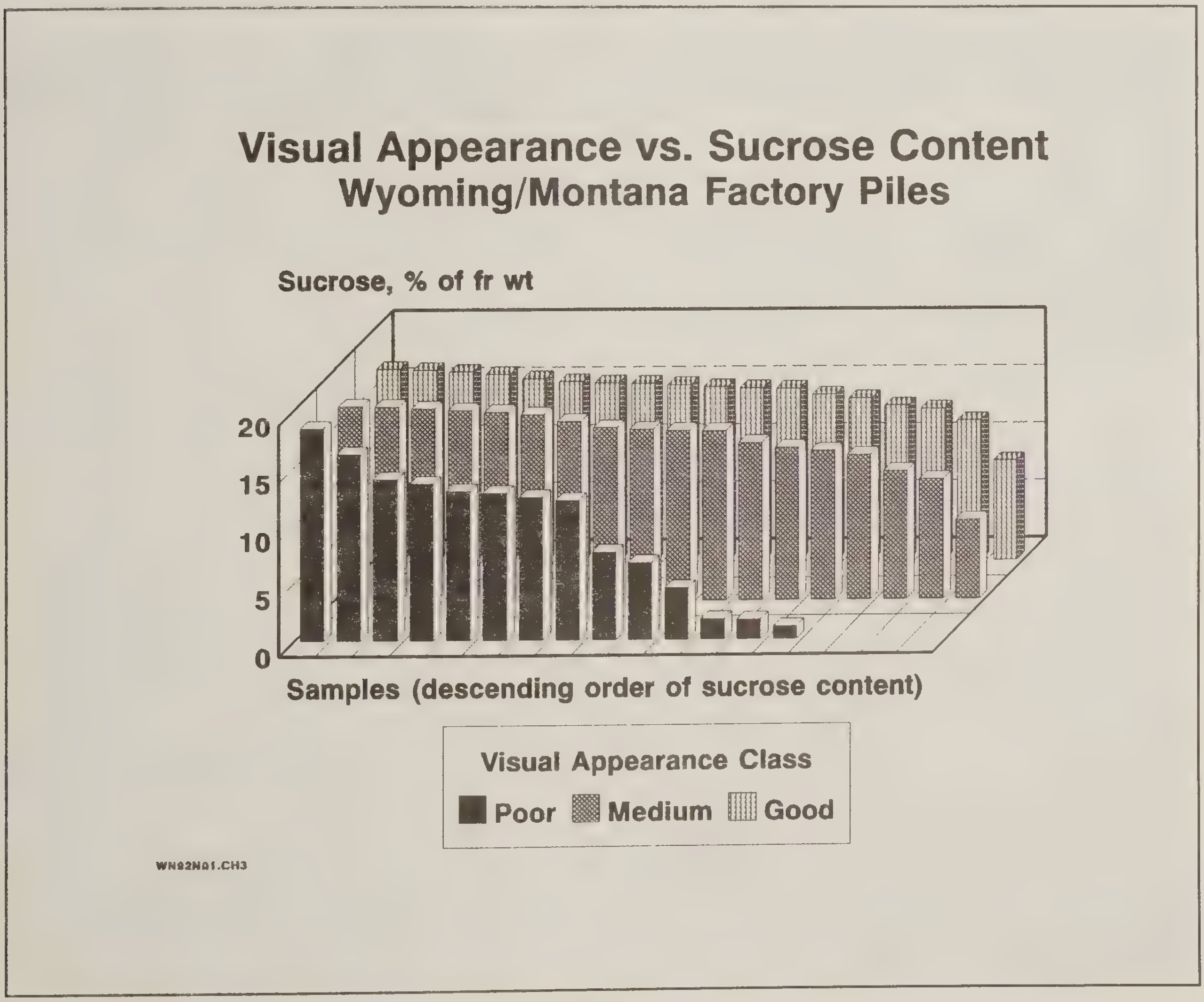
FINDINGS: Polarimetric sucrose analysis of decomposed samples did not even approximately predict the actual sucrose present. This occurred because of the presence of large amounts of other optically active sugars, which caused false polarization values. Typical errors in good-quality samples (sucrose above 14% of root fresh weight) were 5 to 10%, but errors exceeded 100% of the true value in very poor samples. Visual quality was an imperfect measure of processing quality. For example, at one factory, samples visually classified as "Good," "Medium," or "Poor" had true sucrose concentration ranges of 8.7-16.9 (Good), 6.87-17.0 (Medium), and 1.1-18.4 (Poor)[Figure 1]. Monosaccharide levels exceeded values considered to interfere significantly with sucrose recovery in only one "Good" sample, in about half the "Medium" samples, and in all but two

"Poor" samples; levels of raffinose also reached levels detrimental to processing quality in many samples, but this was not uniformly associated with visual quality group.

INTERPRETATION: Visual appearance is not an adequate basis on which to determine processability of decomposing piled sugarbeets. Decomposing sugarbeets may contain large amounts of sugars other than sucrose; the relative proportions of these compounds probably depend on the particular microorganisms present, and on environmental conditions. The presence of these optically active sugar impurities invalidates the use of traditional polarimetric sucrose analyses, and mandates the use of more sophisticated but slower and more expensive analytical techniques. However, the potential monetary return from correct assessment of processing quality clearly would offset the additional cost and time.

FUTURE PLANS: This research was completed in 1992. Plans include presenting the data in a paper and in a manuscript submitted for publication in CY 1993.

Figure 1.



SUGARBEET RESEARCH UNIT

Publications

Lenssen, A.W., Townsend, C.E. and Martin, S.S. 1991. UV-B exposure and incubation times influence accumulation of isoflavonoids in cicer milkvetch. Agron. Abstr. 84:104.

Martin, S.S. and Hoefert, L.L. 1991. Glucosinolate biochemistry and structure of trap crops for the sugar-beet cyst nematode (*Heterodera schachtii*). Amer. J. Bot. Abstr. 78 (Suppl. 6):142.

Martin, S.S., Lenssen, A.W. and Townsend, C.E. 1992. Accumulation of isoflavonoid phytoalexins in diverse *Astragalus cicer*. Amer. J. Bot. Abstr. 79(Suppl. 6):111A.

Martin, S.S. and Narum, J.A. 1992. Biochemical changes in *Beta vulgaris* roots stored under controlled temperature. Amer. J. Bot. 79(Suppl. 6):111B.

Ruppel, E.J. 1991. Survival of *Rhizoctonia solani* in fallow field soil and buried sugarbeet roots at three depths. J. Sugar Beet Res. 28:141-153. (This issue was first published in January 1992.)

TERRESTRIAL ECOSYSTEMS RESEARCH AND ANALYSIS (TERRA) LABORATORY

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MISSION STATEMENT

The mission of the Terrestrial Ecosystems Research and Analysis (TERRA) Laboratory is to be an open, collaborative laboratory; to develop and deliver tools and methodologies for the analysis of interactions among people, land, and natural resources; to benefit and improve land-resource decision making by facilitating use of the tools and methodologies.

TERRESTRIAL ECOSYSTEMS REGIONAL RESEARCH and ANALYSIS

Donn G. DeCoursey
TERRA Unit

CRIS: 5402-61000-002-00D

PROBLEM: The terrestrial component of general circulation models is not in balance with atmospheric and ocean components. Thus the Terrestrial Ecosystems Regional Research and Analysis Laboratory (TERRA) was established in Fort Collins, CO. to work with scientists in improving the terrestrial component. The Laboratory, composed of representatives of the ARS, FS, USGS, and support from the SCS, has now been in operation for about one year. The first 9 months of the year was used in getting organized, moving to Fort Collins and getting the Memorandum of Understanding established. Concurrent with this effort the staff started to developing plans for meeting the mission of the laboratory. Several ideas were considered before calling a meeting of the TERRA advisory committee for review and concurrence. The advisory committee recommended major changes in the program envisioned at that time (May 28-29); thus the staff, after assembling in Fort Collins, re-evaluated the plans. The consensus of the staff was that our first goal should be to concentrate on the last two parts of our mission statement, **To develop and deliver tools and methodologies for the analysis of interactions among people, land, and natural resources,** and **To benefit and improve land-resource decision making by facilitating use of the tools and methodologies.** Part of the rational in reaching this conclusion is the fact that many large laboratories have many millions of dollars devoted to improving the terrestrial component of the GCM's, and we did not think we could make a major contribution at our level of funding. The approach we are taking in meeting the above goals will enable us to make a significant contribution in improving the terrestrial component; it is described below. The problem we have outlined for TERRA is to determine how best to address the two goals identified above. The TERRA staff refer to the approach we are taking as our ***Decision Analysis Methodology***.

APPROACH: Implementing the Decision Analysis Methodology is our approach to meeting the objectives of TERRA's Mission. The Decision Analysis Methodology is a way of aiding the Policy/Decision Maker in evaluating the ramifications of a decision. It uses a computer environment and a series of software programs to complete the assessment. The TERRA staff, working with a facilitator and a group of computer program tools, aids the decision maker in the assessment; all decisions are made by the decision maker. Seven steps in the methodology are:

- define the problem
- define the system geography
- identify likely impacts of change
- define the conceptual structure of the assessment system
- develop formal model of system
- complete analysis of system
- interpret results

Computer tools used to aid in the assessment process are grouped into three different classes:

Decision support software; software designed to aid participants in brainstorming, debating, consensus building, voting and similar activities needed to improve communication in an atmosphere of shared decision making.

Model structure visualization; software designed to expedite development of a model structure using icons that represent processes, data, storage, etc. The icons can be manipulated, expanded, collapsed, and interrogated.

Modeling complex; a collection of models, data bases, parameter values, system states, etc. needed to develop a working version of the model structure developed using the visualization tool.

Implementing the decision analysis methodology is illustrated using a testbed problem. The testbed problem provides a focus for achieving the TERRA goals as well as development of the methodology. Three questions identify what an appropriate problem should investigate:

What are the regional-scale effects of local resource decisions?

What long-term regional effects result from cumulative short-term decision implementations?

What is the relative significance of climatic, biologic, hydrologic, economic, cultural, and demographic factors in resource utilization decisions?

FINDINGS: At the present time the staff is investigating a large group of decision support programs and testing them for application on the testbed problem. Several programs designed for use on PC's are being used in routine discussion and at TERRA work sessions. We are also investigating a package of programs called Advanced Teamkit/2 by IBM that is used in conjunction with a group of linked PC's. The complete system is known as Team Focus. Team Focus is most effective because it enables participants to come to consensus and debate issues anonymously or with attribution. Several visualization tools are also being investigated, but the selection has not yet been made. The Modular Modeling System (MMS), (Leavesley et.al., 1992) has been selected as a prototype for the modeling complex. MMS is an integrated system of computer software that has been developed to support the development, linking, testing, and evaluation of hydrologic-process algorithms and to facilitate the integration of user-selected sets of algorithms into an operational hydrologic model. Even though the system is designed for temporally-sequential hydrologic model development, it is adaptable to many other models (plant growth, environmental, socio-economic). Other modules are being developed at this time. Finally, a testbed problem has been selected. It concerns the utilization of excess water from the Climax Metals Company near Leadville Co. The proposal consists of construction of water handling facilities that will expand an

existing reservoir and enable water to be directed into any one of three drainage basins depending upon the demand and benefits. The specific issue being addressed is: *What are the environmental, social, and economic impacts of executing the Climax Mine reservoir project on a regional scale, as compared to identified alternatives for water sources, water diversion, and potential water customers?*

INTERPRETATION: Progress in implementing the decision analysis methodology on the testbed problem is good. Completion of the project will illustrate the technology and provides a focus for further development. A second testbed problem on the Upper Rio Grand River Basin is being considered.

FUTURE PLANS: A Pert Chart outlining the tasks and a time table for completion of the testbed problem has been developed. The major steps to be completed yet this year are:

- Conduct a series of TERRA work-sessions to complete evaluation of the decision support software, the visualization tools, and the structure of workshops needed to develop the assessment model and the computer version of the model.

- Hold the workshops to develop the model structure.
- Populate the data bases and acquire the modules needed to develop the assessment model.
- Hold a final workshop to make the assessments, analyze the results and aid the decision makers in interpreting them.

WATER MANAGEMENT RESEARCH UNIT

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MISSION STATEMENT

Research emphasis is to integrate applied and basic principles to develop improved water, chemical and alternative weed management systems and irrigation system designs. Improvements are directed towards sustainable, environmentally sound and efficient systems based on soil, water, fertility, energy, and weed ecology principles. This encompasses understanding physical and biological phenomena and developing computer simulation models and expert systems to transfer new technologies to producers, consultants, action agencies, industry and scientists.

FIELD TESTING THE BIOECONOMIC WEED/CORN MANAGEMENT MODEL

Edward E. Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-00D

PROBLEM: Weed control strategies developed since World War II for corn production have encouraged farmers to apply high rates of prophylactic soil-applied herbicides in anticipation of weed problems. The use of herbicides in corn accounts for roughly 40% of all agricultural herbicide use and 25% of all agricultural pesticide use, for a total of 200 million pounds over the nation's 70 million acres of field corn. EPA recently cited all eight major corn herbicides as having been detected in groundwater. Can weeds be managed in corn, gross margins increased, and herbicide surface loading decreased by employing a bioeconomic weed/corn model to make weed management decisions?

APPROACH: Enhanced bioeconomic weed management models for soil-applied and postemergence herbicide treatments were tested on 13 farms in four Colorado counties in 1992. Model decisions were based on weed seed in soil before planting, weed densities after corn emergence, herbicide costs, expected corn grain yield and selling price, and other parameters.

FINDINGS: The results from the 11 farms that provided usable data are summarized in the table. Weed management strategies employed by the model vs the farmers revealed that the model plots had: (1) more annual weeds, (2) yielded 4.1 bu/A more grain, (3) returned $17.90/A more gross margin, (4) cost $7.30 less for herbicides, including application, (5) used 53% less soil-applied herbicide/A, (6) used 5% less postemergence herbicide/A, and (7) used 30% less total herbicide/A. Gross margin advantage/farm favored the model in 7 out of the 11 farms. The gross margin advantage averaged $31.20/farm for the model vs $5.40/farm for the farmer.

INTERPRETATION: Weeds can be managed in corn, gross margins increased, and herbicide surface loading decreased by employing bioeconomic weed/corn models to make weed management decisions.

Overall Summary of the 1992 Pilot Test in four counties

Description	Farmer plots	Model plots
Weeds at Harvest (No./100 ft of row)		
Grass	17	13
Broadleaves	3	13
Total weeds	20	26
Grain Yield (Bu/A)	181.1	185.2
Gross Margin ($/A)	442.90	460.80
Herbicide Costs		
Preplant ($/A)	3.16	0.00
Preemergence ($/A)	4.00	4.59
Postemergence ($/A)	12.87	8.13
Total ($/A)	20.03	12.72
Herbicide/Soil Loading		
Soil-Applied		
Preplant (Lb/A)	0.49	0.00
Preemergence (Lb/A)	0.69	0.55
Total (Lb/A)	1.18	0.55
Postemergence (Lb/A)	0.81	0.85
Total Herbicide (Lb/A)	1.99	1.40

FUTURE PLANS: Testing and validation of the enhanced bioeconomic weed management models for soil-applied and postemergence herbicide decisions in corn were completed in 1992. Data from this four-year research project will be analyzed, summarized, and published.

WEED MANAGEMENT IN CORN BASED ON TILLAGE VS COMPUTER DECISIONS

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Water Management Research Unit

CRIS: 5402-22000-002-00D

PROBLEM: New emphasis on alternative agriculture methods that eliminate or replace part of a herbicide program with mechanical tillage necessitates precision research to determine whether computer-based weed management models can be adapted to provide weed management decisions for alternative farming systems. Additionally, few reports have been published on the effectiveness of mechanical tillage to control weeds in row crops over the last 40 years because weed control strategies developed since World War II for crop production have encouraged farmers to apply high rates of prophylactic soil applied herbicides in anticipation of weed problems. Weeds that emerge within the crop row were difficult to control when they emerge simultaneously with the crop. Thus, if weeds are to be controlled within the crop row with mechanical tillage, better methods must be sought.

APPROACH: The efficacy of non-herbicide mechanical methods versus computer decisions for control of annual weeds under different weed pressures was assessed in corn. Variables were: weed seed banks, pre-cultivation tillage at crop emergence, and cultivation after corn establishment. Experimental design was a split-plot. Weed management strategies (treatments) were randomized within each block in 1990, but not re-randomized in 1991 and 1992. Thus, each strategy's location in 1992 was fixed. This design allowed the tracking of each strategy on a given plot over the 3-year study. This study permitted the assessment of the effectiveness of a rotary hoe vs a flex harrow and a standard cultivator versus an in-row cultivator to control weeds within the row when corn is grown under different different weed pressures. Weed control was assessed following each tillage practice. Weed management strategies were compared in terms of weed control, crop grain yield, and gross margin (gross income minus weed control costs).

FINDINGS: In the absence of herbicides, weed populations in corn were reduced six times more with an in-row cultivator as compared to a standard cultivator (see table). As expected, where herbicides were not used, weed populations were higher than where weed management decisions were based on the computer model. Corn populations, grain yield, and gross margin were similar irrespective of weed seed bank, type of cultivator, or weed management strategy.

INTERPRETATION: Weeds were controlled better with the in-row cultivator than with the standard cultivator. When corn can emerge two to three weeks before weeds, weeds can be controlled effectively with tillage. When corn and weeds emerge together, as they did in 1991, the in-row cultivator can be used effectively to control weeds within the corn row. However, when tillage is delayed in a wet spring, weed control, grain yield, and gross margin will be higher when the bioeconomic weed/corn model is employed. Although corn can be

produced without herbicides in a wet year, fields will be weedier at harvest and gross margins less than where weed decisions are based on the computer model.

Parameter	Total weeds[a] at harvest (#/100 ft)	Corn stand (#/100 row ft)	Grain yield (Bu/A)	Gross margin ($/A)
Weed seed level				
Low	51a	166a	165.7a	395.10a
High	32a	163a	167.2a	400.70a
Cultivator				
Standard	71a	169a	166.8a	399.90a
In-row	12b	160b	166.0a	395.80a
Weed mgt. strategy				
Tillage only	60a	166a	167.4a	405.00a
Computer model	23b	163a	165.5a	390.80b

[a]Means followed by the same letter for each parameter and within each column are not different.

FUTURE PLANS: This three-year research was completed in 1992. Data will be analyzed, summarized, and published.

DEMONSTATION OF A COMPUTER BIOECONOMIC MODEL FOR WEED MANAGEMENT DECISIONS FOR CORN PRODUCERS

Phillip Westra and Edward E. Schweizer
Water Management Research Unit

CRIS: 0500-00002-006-01S

PROBLEM: Computer bioeconomic models that make decisions for weed management in agronomic crops were not available until the weed/corn bioeconomic model was developed scientists in the mid 80's in a cooperative endeavour between Colorado State University and the Agricultral Research Service of the USDA.

APPROACH: The model was demonstrated to farmers, extension agents, crop consultants, chemical dealers, and to scientists at other univerities. Interested parties were also informed about the model through the popular press and field days.

FINDINGS: Research and educational activities utilizing the weed/corn management model from 1989 through 1992 confirmed the fact that this new technology presents corn producers with an important new tool which can help reduce herbicide rates up to 15% while maintaining weed control and profitability. Project activities in 1992 related to development of a 20-minute educational video highlighting problems associated with over-reliance on herbicides for weed control, and the utility of the corn bioeconomic model to assist farmers in making rational decisions about herbicide use in corn. Eighty copies of the completed video were delivered to Colorado State University in November 1992. Copies were sent to key cooperative extension agents, farmers, and crop consultants in Colorado, and to key weed scientists in MI, IN, IL, WI, MN, IA, NE, KS, and CO. This video appeals to both rural and urban audiences since it addresses key environmental concerns shared by both producers and consumers of agricultural crop products. The video highlights the significant contributions of CSU, USDA/ARS, and EPA.

Development of educational activities for the bioeconomic modelling project has taken several forms. This involved gathering master footage of field operations; interviewing corn producers, cooperative extension agents, water quality specialists, and scientists; and shooting key components of the bioeconomic model, i.e., sampling and extracting weed seeds from soil, weed seedling counts, running the computer model, and implementing weed management strategies. The video was narrated by a professional narrator from Denver.

Articles in trade magazines, and requests for reports at state pest management conferences have allowed us to expose a broad range of audiences to the Colorado computer model. These presentations have included the Illinois ag-chemical workshop, the Colorado corn clinic, the agronomy departments in Colorado, Illinois, New York, and Washington, the NC-202 1992 summer meeting, and the Weed Science Society of America and the Western Society of Weed Science meetings.

Copies of the video can be obtained from Dr. Phi Westra, Department of Plant Pathology and Weed Science, Colorado State University.

FUTURE PLANS: This CRIS was terminated in October 1992.

ECONOMIC FEASIBILITY OF COMPUTER BIOECONOMIC MODEL FOR WEED MANAGEMENT

Donald Lybecker and Edward E. Schweizer
Water Management Research Unit

CRIS: 0500-00002-006-02S

PROBLEM: Relatively little research has been directed toward the economics of weed management. Few bioeconomic weed-crop models have been developed or field tested. Weed-crop models could aid growers and crop consultants to compare the biological and economic efficiency of many alternatives and present easily interpreted recommendations.

APPROACH: Enhanced bioeconomic weed management models for soil-applied and postemergence herbicide treatments were tested on 15 farms in four Colorado counties in 1991. Model decisions were based on weed seed in soil before planting, weed densities after corn emergence, herbicide costs, expected corn grain yield and selling price, and other parameters. ARS and CSU personnel collected and analyzed soil samples from each farm for weed seed, made all plant assessments, and applied all herbicides to model plots. Farmers performed all cultural practices and harvested corn in their strips and in the model plots.

FINDINGS: The Colorado soil applied and postemergence bioeconomic weed-corn models were annually updated to reflect herbicide labels changes and the introduction of new herbicides. The models were validated on 39 eastern Colorado farms in 1989-1991. Results from three years of pilot testing showed that (1) farmers tended to apply more soil applied treatments and the model more postemergence treatments, (2) model strategies reduced the pounds of herbicides applied/A by 10 to 20%, (3) the model typically did not prescribe a soil-applied herbicide unless the weed seedbank was greater than 21 million seeds/A, (4) two out of three times the model strategies out performed the farmers normal weed management strategy by an average of $14.00/A, and (5) one-third of the time the normal farmer strategy out performed the model strategy by $20.20/A. Simulation analysis using the soil applied model of potential atrazine and triazine bans in Colorado corn concluded that yields and gross margins would be reduced on average less than 2%. The analysis assumed a typical Colorado irrigated soil and a weed species mix based upon the pilot test farms for a range of grass and broadleaf seedbank levels.

INTERPRETATION: The models will be useful and profitable for individuals who lack strong weed management skills, on fields with no weed history, and for professionals who want to effectively consider a wide range of herbicides for alternative weed densities and weed species mixes.

FUTURE PLANS: This CRIS was terminated in October 1992. Data from this four-year research project will be analyzed, summarized, and published.

REFINEMENT OF THE COLORADO WEED/CORN AND DEVELOPMENT OF EDUCATIONAL MATERIALS FOR END USERS

Donald W. Lybecker, Phillip Westra and Edward E. Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-02S

PROBLEM: Little research has been directed toward the economics of weed management. Few bioeconomic weed-crop models have been developed or field tested. Weed-crop models could aid growers and crop consultants to compare the biological and economic efficiency of many alternatives and present easily interpreted recommendations.

APPROACH: Enhanced bioeconomic weed management models for soil-applied and postemergence herbicide treatments were tested on 13 farms in four Colorado counties in 1992. Model decisions were based on weed seed in soil before planting, weed densities after corn emergence, herbicide costs, expected corn grain yield and selling price, and other parameters. ARS and CSU personnel collected and analyzed soil samples from each farm for weed seed, made all plant assessments, and applied all herbicides to model plots. Farmers performed all cultural practices and harvested corn in their strips and in the model plots.

Development of educational activities for the bioeconomic modelling project included obtaining master footage of field activities, including sampling and extracting weed seeds from soil, weed seedling counts, running the computer model, and interviewing corn producers, cooperative extension agents, water quality specialists, and scientists involved in the development of the model. During 1992 the master tape footage was edited and narrated, using a professional narrator, to produce the final 20-minute video.

FINDINGS: The weed/corn bioeconomic model was updated to reflect herbicide label and price changes. Eleven of the 13 pilot test sites provided usable data. Gross income of the model plots averaged $10.60/A more than the farmer plots (see table). At 7 of the 11 sites the model out performed the farmer plots by an average of $31.20/A. At the other four sites the farmer plots had a higher average gross margin of $5.40/A. Over all sites, the model plots outperformed the farmer plots by more than $17.90/A, and farmers spent an average of $7.30/A more for herbicides compared to the model plots. The farmer herbicide expenditures were more for both soil-applied and postemergence herbicides. A template to determine the herbicide rates for the weed/corn model based on soil structure and organic matter was developed. A preliminary Herbicide Environmental Index was developed and is being evaluated with pilot test data. Herbicide quantity (#AI), toxicity, persistency, and mobility are index components.

Copies of the 20-minute educational video were sent to key cooperative extension agents, farmers, and crop consultants in Colorado, and to key weed scientists in nine states. The bioeconomic model was presented at an Illinois ag-chemical workshop at meetings of NC-202, Weed Science Society of America, and American Chemical Society.

Economic Analysis of the 1992 Pilot Test Plots

Item	Farmer Plots	Model Plots	Difference
Yield (Bu/Ac)	181.1	185.2	4.1
Price ($/Bu)	2.56	2.56	----
Gross Income ($/Ac)	462.90	473.60	10.60
Cost SA Treatment ($/Ac)	7.16	4.59	2.57
Cost of Post Treatment ($/Ac)	12.87	8.13	4.74
Total Herbicide Cost ($/Ac)	20.03	12.72	7.30
Gross Margin ($/Ac)	442.90	460.80	17.90
Number of Plots Greater Gross Margin (No.)	4	7	5
Gross Margin for Plots (Farmer or Model) with higher Gross Margin ($/Ac)	5.40	31.20	----

INTERPRETATION: Based on four years of data from 50 farm sites, the model suggests that increased gross margins and reduced herbicide loading can be achieved with the weed management model compared to farmer weed management decisions. Transfer of this technology to the Corn Belt States should lead to reduced herbicide use.

FUTURE PLANS: This four-year pilot field research project was completed in 1992. Data will be analyzed, summarized, and published. Lybecker and Westra will complete the EPA portion of this agreement by September 30, 1994.

DECISION AIDS TO MANAGE WEEDS IN CORN AND SOYBEANS IN MINNESOTA

Robb King, Doug Buhler, Bruce Maxwell, and Edward Schweizer
Weed Management Research Unit

CRIS: 5402-22000-002-03

PROBLEM: The use of herbicides on corn accounts for roughly 40% of all agricultural herbicide use and 25% of agricultural pesticide use, for a total of 200 million pounds over the nation's 70 million acres of field corn. The bioeconomic weed-corn modeling technology developed by ARS and Colorado State University scientists provides many options for corn producers to use this technology to reduce reliance on herbicides. Since this technology is contributing to the Presidential Initiative on Enhancing Water Quality, ARS and EPA wanted this technology adapted for rainfed agriculture.

APPROACH: The Colorado technology was shared with scientists at the University of Minnesota so they could: 1) modify, refine, and upgrade the Colorado technology to reflect local conditions for their corn producers, and 2) build a prototype weed-soybean model. The corn/soybean model (WEEDSIM) was validated in field trials in 1992 and field research on weed/crop interactions and weed population dynamics needed to improve the prediction power of WEEDSIM were undertaken at the Rosemount research center.

FINDINGS: In a corn experiment, herbicide load was reduced from the 4.5 lb/A with the standard herbicide to 3.5 lb/A with the seed bank model, 3.0 lb/A with the adjusted seed bank model, and to 2.0 lb/A with the postemergence model. Costs of the weed management treatments ranged from $14.30/A for the mechanical system to $31.20 for the standard chemical. All three model-generated treatments had lower costs than the standard chemical treatment. Control of giant foxtail, redroot pigweed, and common lambsquarters was similar to the standard with the postemergence model treatment. However, giant foxtail control was less with the two seed bank model treatments than the standard chemical treatment. Control of giant foxtail, redroot pigweed, and common lambsquarters was less with the mechanical control system than all other treatments. Corn yields with the postemergence model treatment were similar to the standard chemical treatment, but yields for the two seed bank model treatments were less than the chemical standard. The mechanical weed control system resulted in lower corn yield than all other treatments due to poorer weed control. The standard chemical and postemergence model treatments had similar net margins that were greater than the two seed bank model treatments.

In the soybean experiment, herbicide load was 0.75 lb/A with the standard chemical treatment, 0.76 lb/A with the seed bank model, 0.2 lb/A with the adjusted seed bank model treatment, and 0.06 lb/A with the postemergence model. Weed management costs with the postemergence model and the adjusted seed bank treatment were similar to the standard. Cost of the seed bank model treatment was higher than other treatments. The seed bank model treatment controlled more giant foxtail than all other treatments. Control of common lambsquarters and redroot pigweed with the seed bank and postemergence model treatments were

similar to the standard. Control of common lambsquarters and redroot pigweed with the adjusted seed bank treatment was less than with other model-generated treatments and the chemical standard. Although there were differences in weed control among weed management treatments, no differences in soybean yield were observed.

INTERPRETATION: Compared to the standard chemical treatment, all model-generated treatments reduced herbicide use in corn. The postemergence model resulted in weed control, corn yield, and net margin similar to the chemical standard. However, the seed bank model treatments had lower corn yields and net margins than the standard due to a lower level of weed control. There appear to be several environmental and model-related causes for the poor performance of the seed bank model in 1992. These potential problems have been identified and the model is currently being adjusted based on these results and new data that has been generated in other experiments.

The results from the soybean validation experiment are very encouraging. Changes made to the soybean model following the 1991 experiment appear to have improved model performance. The data obtained from this experiment will be used to further improve and expand the current model.

FUTURE PLANS: Discussions are under way with potential cooperators for large scale field site testing of the bioeconomic model in 1993. Transfer of the model to other states is under way through the activities of NC-202. In cooperation with researchers from Colorado and Michigan, a publication on weed control economics has been drafted.

IMPROVING WEED CONTROL AND WATER QUALITY WITH TILLAGE AND LESS HERBICIDE

Mark VanGessel, Phillip Westra, and Edward Schweizer
Water Management Research Unit

CRIS: 0500-00032-021-01S

PROBLEM: Alachlor is commonly used as a soil-applied herbicide to control weeds in corn. However, it has been detected in surface water and ground water. If lower rates of alachlor could be used to control weeds in corn, the risk of water contamination would be reduced accordingly. Early-season weed control is important to minimize weed competition, to increase grain yields, and prevent hindering cultural operations. Early season weed control tactics generally focuses on soil-applied herbicides and mechanical tillage, i.e., rotary hoeing and/or cultivation. In practice, growers generally apply herbicides at planting and rotary hoe when soil crusting may impede corn emergence. Since information is sparse on the weed control interactions between reduced herbicide rates and mechanical tillage, this research was undertaken in 1992.

APPROACH: Reduced rates of alachlor (Lasso) when supplemented or replaced with tillage at crop emergence and/or cultivation was assessed for the control of annual weeds in corn. Variables examined were: soil weed seedbanks (low, medium, and high); rate of alachlor (none, one-third (0.3X), and two-thirds (0.6X) of the labeled recommended rate); tillage at crop emergence (none, one or two passes with a rotary hoe); cultivation (standard vs in-row cultivator); and postemergence herbicides (POST), if any, as recommended by the ARS/Colorado weed/corn bioeconomic model. The experimental design was a split-split block arranged as a randomized complete block with four replications. The whole plots were an incomplete factorial arrangement of crop emergence tillage, cultivation, and POST within each weed seed bank level (first split). The second split was alachlor rate. This study allowed for the assessment of alachlor rate with a variety of weed management strategies at three levels of the weed seedbank. Weed control was assessed by counting weeds within each subplot. Corn grain was harvested in each subplot and grain moisture adjusted to 15.5%. Weed management efficacy was determined in terms of weed control, weed management costs, grain yield, and gross margin (gross income minus weed control costs).

FINDINGS: Weed seedbanks had no impact on results in 1992. Weed control from alachlor rates and emergence tillage was assessed prior to cultivation. Weed control was more effective with 0.3X and 0.6X rate of alachlor than no alachlor. Two passes of the rotary hoe reduced the stand of weeds more than one pass. When weed control was assessed after the last cultivation, the in-row cultivator provided much better control than the standard cultivator. As expected, POST treatments significantly reduced weed populations compared to no POST. Impact of alachlor on weed control just prior to harvest was similar to the June assessment, but weed populations were similar in rotary hoed plots vs non-rotary hoed plots. Due to low weed populations, yields were similar for all treatments. Gross margins were highest for those treatments with the least cost of weed control, i.e., standard cultivator vs the in-row cultivator and no Post vs Post.

Parameter	Total weeds #/100 row ft	Corn stand #/100 row ft	Grain yield (Bu/A)	Gross Margin ($/A)
<u>Alachlor rates</u>				
None	152	164	177	425
One-third (0.3X)	40	166	182	436
Two-thirds (0.6X)	22	164	182	433
<u>Emergence tillage</u>				
None	154	164	179	429
One rotary hoe	34	164	182	434
Two rotary hoe	20	164	181	431
<u>Cultivation</u>				
Standard	160	166	182	441
In-row cultivator	42	164	180	428
<u>Postemergence herbicide</u>				
None	104	164	181	436
Model	18	164	180	425

INTERPRETATION: Under situations of low weed populations, minimizing inputs for weed control will increase growers gross margins. Additional inputs generally did not result in significantly better weed control while increasing costs. When the spectrum of weeds is comprised of species highly susceptible to alachlor, reducing the rate of alachlor can provide adequate control while reducing costs and lowering the risk of ground water and surface water contamination.

FUTURE PLANS: This experiment will be repeated in 1993. Additional analyses will be performed on the data to examine the interactions between mechanical and chemical weed control.

PROTECTING WATER QUALITY BY SCOUTING WEED POPULATIONS

L. J. Wiles and E. E. Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-04R

PROBLEM: Weed control with herbicides is economic, convenient and effective. As a result, herbicides have lead the dramatic, recent increase in the amount of pesticide applied with corn and soybeans receiving approximately 70% of the total amount used. Herbicides are also the pesticide most commonly detected in groundwater in the corn belt. Corn and soybean herbicides have also been seasonally detected in surface waters. More efficient weed management can enhance the quality of groundwater and surface water by reducing the use of herbicides.

APPROACH: Weed management could be more efficient if growers had more accurate, field-specific information about the composition and spatial arrangement of weed populations. Applications could be limited to fields, or portions of fields, for which control is economically justified. Treatments could be carefully matched to the composition and spatial distribution of the population in each field, and growers could identify fields in which selective, postemergence treatments can be substituted for prophylactic soil-applied treatments. Herbicide use should be reduced with no loss in net profit.

The spatial distribution of weeds in corn and soybean fields will be characterized. This information will be used to develop efficient scouting plans for obtaining weed population information needed when using corn and soybean weed management decision aids. The potential for reduced herbicide use with spatially-variable weed control treatment in corn and soybean fields will also be assessed.

FINDINGS: Agricultural consultants have identified potential commercial Colorado corn fields and Nebraska soybean fields for sampling of weed populations during the 1992/93 growing season. The initial sampling protocol has been designed and equipment for sampling has been purchased. The weed seed bank population in one Colorado corn field has been sampled.

Because agricultural consultants and growers are the potential users of this technology, it is important to make these groups aware of this research even at its early stage. This research project has been briefly discussed in a 20 minute video highlighting problems associated with over-reliance on herbicides for weed control, at a corn pest management clinic held at Colorado State University and also at the annual meeting of the Independent Agricultural Consultants of Colorado. Discussions with growers and consultants indicate that they are interested in having more information about the weed populations in their fields, but that they also are aware of the potentially high cost of collecting that information.

INTERPRETATION: Many growers and consultants recognize that having information about the composition and spatial arrangement of a weed population could help them make better weed management decisions. However, they are concerned about

the cost of scouting to collect this information. This research will quantify the cost of scouting and the value of the information obtained and also will help identify efficient scouting plans.

FUTURE PLANS: The weed seedling and seedbank populations in five commercial corn fields in Colorado will be sampled in 1993. This information will be the basis of simulation experiments to identify optimal scouting strategies as well as the value of spatially variable weed control within a field.

PROTECTING WATER QUALITY BY SCOUTING WEED POPULATIONS IN SOYBEAN FIELDS

D. A. Mortenson, L. J. Wiles and E. E. Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-04R

PROBLEM: Pesticides are apparently reaching the groundwater and surface waters from routine agricultural use. In the corn belt, soybean herbicides have been detected in groundwater and seasonally in surface waters. More efficient management of weeds in soybean fields can enhance the quality of groundwater and surface waters by reducing the use of herbicides.

APPROACH: Having accurate, field-specific information about weed populations can help growers manage weed populations more efficiently. Applications can be limited to fields, or portions of fields, for which control is economically justified. Treatments could be carefully matched to the composition and spatial distribution of the population in each field, and growers could identify fields in which selective, postemergence control can be substituted for prophylactic, soil-applied treatment. A microcomputer expert system is available to help growers with weed management decisions in soybeans. Simulation experiments will be done to develop a scouting plan for use with this expert system and to determine the value of modifying the model to recommend spatially variable weed control treatments within a field.

FINDINGS: This research will be initiated in 1993.

FUTURE PLANS: The seedling populations in five commercial soybean fields will be sampled in 1993 and the data will be used to model weed spatial distribution, an important input for the simulation experiments. Agricultural consultants will help design the algorithms for spatially variable treatment decisions and the scouting plans that will be tested in the simulation experiments.

BIOECONOMIC WEED MANAGEMENT DECISION AIDS FOR BARLEY AND DRY BEAN PRODUCTION

L. J. Wiles and E. E. Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-00D

PROBLEM: Herbicides are apparently reaching groundwater and surface waters as a result of current crop production practices. Herbicide use can be reduced without compromising net profit through more efficient weed management. Water quality may be protected by helping growers manage weed populations more efficiently.

APPROACH: The use of bioeconomic weed management decision aids can increase the efficiency of weed management and thereby, reduce herbicide use. These programs can help decision makers match the selectivity of a control treatment to the composition of the anticipated or actual weed populations. These programs can also do a cost/benefit analysis to ensure that control is used only when the benefits are expected to exceed the costs. A reduction of herbicide use, in comparison to intensive, prophylactic herbicide use has been documented for the use of two existing programs. While herbicide use was reduced, net profit was maintained or increased. The objective of this work is to develop bioeconomic decision aids for weed management decisions in irrigated pinto beans and barley.

FINDINGS: A general or "generic" weed management decision model and an associated database management system to modify model parameters and inputs has been developed in cooperation with Dr. Rob King at the University of Minnesota. The decision module was programmed in Visual BASIC using a database management library (db/LIB). The database management system was programmed in CLIPPER. The link between the two components is a series of databases in dBaseIII format. This general, flexible system was developed to minimize the programming required to develop models for different crops or to modify the inputs and parameters for crop production in another region. In addition, a common format for weed management decision models will make it easier to link models to examine weed control decisions within a crop rotation.

The dry bean and barley weed management models are being developed by parameterizing the general model from information in the literature and expert opinion. Discussions with experts from Colorado, Nebraska and Wyoming highlighted the importance of modeling weed seed germination through time and the effect of the presence of weeds at harvest on bean quality in a dry bean weed management decision model. Experiments were conducted in Colorado and Nebraska to examine the pattern of weed emergence in dry beans and the effect of weed control treatment on these patterns.

INTERPRETATION: Developing weed management decision models is one way to help growers reduce herbicide use, and as a result, protect water quality. A general weed management decision model was structured and programmed as a first step in developing weed management models for dry bean and barley production. The common, general structure will make it easier to modify the models for crop

production in different regions. It should also facilitate linking models for different crops together to help growers with weed management decisions within the context of a crop rotation.

FUTURE PLANS: The prototype of the dry bean model will be ready for field testing this spring. In addition, the general model and database system will be distributed to weed scientists throughout the corn belt for their review and comments. The barley prototype will be ready for field testing in 1994.

SAFETY AND WATER SUPPLY PROTECTION WHEN APPLYING AGRICULTURAL CHEMICALS IN IRRIGATION WATER

E.G. Kruse, H.R. Duke and G.W. Buchleiter
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Advantages of agricultural chemical application in irrigation water include potential for uniform coverage, low application costs, fewer restrictions on application timing than when mobile, ground based applicators are used, and, with automated irrigation systems, the possibility of applying materials toxic to humans with minimal human exposure. Disadvantages are potential contamination of irrigation water supplies, high levels of dilution of chemicals with irrigaton water, and limited ability to pinpoint applications to those portions of the plant or soil where the pesticide might be most effective.

Several states have researched various elements of "chemigation" and/or have developed laws to regulate the practice. Variations in regulations or in research results suggest that information should be consolidated nationally, and additional research initiated, if indicated. For example, little is known about the functional life of hardware used for chemigation safety, and the interaction of different chemicals and water qualitites on the effectiveness of such equipment.

APPROACH: Our initial research interest is with proper design and maintenance of equipment for injecting chemicals into irrigation systems, especially pressurized systems, so that irrigation water supplies are protected from contamination. In 1991, Dr. Duke conducted an extensive search of the chemigation literature and contacted many researchers who have experience in chemigation studies. Several states have legislated licensing and periodic inspection of chemigation hardware to assure that those components necessary to prevent spills and backflows are in place and functioning properly. Records of such inspections could provide a good source of information as to the effectiveness of current safeguards and could indicate areas where more research is needed. At the initiation of our unit, the North Central regional research project NC-163 added an objective whereby NC-163 members are encouraged to work with appropriate state agencies to analyze existing records to reveal shortcomings in safety equipment now required by the state, identify safety system components most likely to malfunction, and identify futher research necesary to assure proper performance of safety equipment.

FINDINGS: Colorado, through the Commissioner of Agriculture, regulates chemigation systems in the state. Systems are inspected every two years to assure their compliance with standards. During 1990-1992, Colorado inspected about 3000 chemigation systems. Of the 106 that failed to pass, 25 lacked permits, 62 were missing some or all required components, 7 were improperly installed. Only four equipment shortcomings were noted, always the main line check valve that is intended to prevent the chemical/water solution from reaching the irrigation water supply if the water supply pump should stop.

INTERPRETATIONS: If examination of chemigation records from other states confirms Colorado experience, it would seem that proper use of chemigation will result from better education of producers with regard to the necessity of permits, and proper installation of all required safety components. The fact that 96.5% of Colorado systems had the required, properly functioning safety components in place when inspected, provides a high degree, but not absolute certainty that those components would work as intended, as a system, to prevent chemical spills.

FUTURE PLANS: No further work is planned for this project at this time.

WATER USE AND LABOR REQUIREMENTS FOR IRRIGATED CROPS

E. Gordon Kruse
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Accurate estimates of crop water use are necessary for irrigation scheduling, which in turn allows good irrigation water management. High water tables often exist under irrigated lands as a result of inefficient irrigation systems and subsurface geological conditions. Such water tables occur under much of the irrigated land in the Upper Colorado River Basin. Irrigation management should take crop water use from shallow water tables into account, and modify irrigations accordingly. Also, more information is needed on the benefits of level basin irrigation, relative to more traditional methods of surface irrigation.

Vegetables and other specialty crops are often grown under plastic mulch, which can affect both water use and the efficiency of application of irrigation water. Little information is available on mulch effects on root development and water requirements. The interactions between water and nitrogen applications needs to be better understood for all crops to increase efficiency of N utilization and minimize ground-water pollution potential.

APPROACH: Field studies of crop water use from shallow water tables and of labor and water requirements for surface irrigation were described in last year's report.

A cooperative study with the CSU Dept. of Horticulture continued in 1992, to determine effects of plastic mulch on water use, rooting pattern, and irrigation scheduling of vegetable crops irrigated by trickle or furrow methods. Small plot treatments were evaluated by root sampling and statistical analyses of plot yields and water use efficiencies. Another study examined soil nitrates under a range of irrigation and fertilizer applications to onions in the Arkansas River Valley.

FINDINGS: Results of the study of shallow, saline ground water contributions to crop needs have been submitted for publication. Detailed records of gross water use and labor required for irrigation of all fields on the main 80 acre portion of the Fruita Res. Ctr. during 1989, were analyzed and a manuscript drafted.

Squash, grown under black plastic mulch, and trickle and furrow irrigated at half the scheduled rate yielded as much as a furrow plot irrigated at the scheduled rate. Water Use Efficiency was highest for mulched squash with trickle irrigation, but only slightly lower for mulched, furrow irrigated squash receiving the same volume of water. High growing season precipitation in 1992 (222 mm) may have masked effects of irrigation treatements. 1992 root distributions are being analyzed.

A three year study of irrigation/fertilizer interactions on onions in the Arkansas Valley showed that onion yields could exceed 50 T/ha without nitrogen fertilization if initial soil nitrate-N levels exceeded 42 ppm. Irrigations equal to 75 percent of the scheduled amount were sufficient for maximum yield. When twice the estimated irrigaton requirement was applied, up to 1400 kg/ha of

nitrate-N was unaccounted for and was presumed to have been leached below the top 2 meters of the soil profile or denitrified.

INTERPRETATION: Water tables with depths to 1 meter can contribute significant portions of the water needs of corn, wheat and alfalfa. Depth of water table affects the portion to a greater extent than soil water salinity, up to electrical conductivities of 6 deciSiemens per meter. Under shallow water table conditions, root zone salinity must be closely monitored to detect salt accumulations and need for leaching.

Bush-type squash grown over black plastic mulch developed more quickly than non-mulched, and yielded 20 to 25 percent more for the same irrigation treatments. Water Use Efficiencies were highest for mulched treatments irrigated through a trickle line laid under the mulch, and receiving half the irrigation water indicated for non-mulched, furrow irrigated squash. Preliminary analysis of root distributions shows that more than 60 percent of root mass is in the top 15 cm of soil, that irrigation level does not affect root pattern, and that a larger percentage of root mass occurs close to the plant stem (under the plastic) for mulched plants. Plastic mulch and trickle irrigation will become cost effective for high-value crops as irrigation water costs increase.

Pre-season analysis of soil nitrates is important to determine if additional nitrogen should be supplied for onion culture. Irrigation applications should be no greater than those called for by the USDA irrigation scheduling program, if maximum yields are to be obtained with minimum opportunity for ground-water pollution by nitrates.

FUTURE PLANS: Dr. Kruse has applied for Collaborator status, following his retirement from ARS in April, 1993. He will continue to pursue publication of research results from the Grand Valley and of the cooperative studies with CSU Dept. of Horticulture.

ARS LIAISON TO SCS

Dale F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: The Technology Information Systems Division (TISD) of the SCS is responsible to develop, support, and maintain a technology information system (TECHIS). The system consists of conservation planning resource inventory, conservation effects, and practice design tools together with supporting data bases needed by SCS National Headquarters, State, area, and field offices to carry out their tasks. ARS has an extensive history of developing new technology which has been used by SCS. The need exists to improve ARS cooperation with our customer (SCS) to appropriately transfer the ARS developed technology and establish protocols for establishing high priority research projects within ARS.

APPROACH: The liaison role will be to assist in the development of protocols for cooperation or partnership which will enhance the development and delivery of technology by ARS and SCS. My time will be split between my RL responsibilities for the Water Management Research Unit and the liaison position. I will meet and interact with the SCS TISD division in Fort Collins. An office will be provided and should be available by March 1, 1993.

FINDINGS: Several meetings were attended where the user requirements were developed with joint meetings with representatives from the SCS, Extension Service and CSRS. The project is now operating under the name SWAN which is descriptive of an operational soil water and nitrogen model. This project has been assigned to Dr. Buchleiter for an exercise for the Systems Engineering Training program. An ARS/SCS partnering workshop was held in December to explore opportunities to improve the development and delivery of natural resource technology through information systems to the SCS field offices.

INTERPRETATION: The ARS must better identify our customers to meet our research objectives of solving current problems. The ARS\SCS partnering is an excellent way for us to interact with one of our major customers. This could greatly impact our ability to continue as a major player in natural resource research in the USDA.

FUTURE PLANS: The next year will be devoted to learning the needs of SCS in packaging technology for field use, communicating these needs to appropriate ARS scientists, advise SCS of useful technology available in ARS, and develop protocols for cooperation. I intend to become actively involved in evaluating the current technology used by SCS and possibly do evaluation of alternatives as time permits.

DESIGN CRITERIA & INTEGRATED MANAGEMENT TECHNOLOGY FOR SURFACE & CENTER PIVOT IRRIGATION SYSTEMS

Dale F. Heermann, ADODR and Clyde Fraisse
Water Management Research Unit

CRIS: 5402-13000-004-03S, SCA 58-5402-0-003

PROBLEM: The management of irrigation systems to apply water and chemicals is needed to increase water use efficiency and prevent the degradation of ground water. The integration of management is important to provide for improved operation. When managing any resource by itself can lead to mismanagement of another resource. The implementation of integrated systems requires the necessary hardware and software for testing and developing new concepts.

APPROACH: A linear move system for experimental water and chemical application requires a control much more sophisticated than one for normal field operations. The different water treatments required are often applied by changing frequency and/or depth of an irrigation. The system to be installed at the CSU North Ag Campus will require flexibility in both time and space. A possible solution for the problem of varied application needs along the pipeline is to apply the concept of pulse irrigation. Pulse irrigation is based on a series of pulses, where each pulse is composed of the operating (on) and resting (off) phases. Solenoid valves installed upstream of one or more spray heads enable the flow control. Because each electrical pulse causes the valve to perform one complete cycle, the frequency of operation is limited by the valve's response time. When compared to mechanical valves, solenoid valves are usually lighter and more compact. Unlike manual actuators, solenoids allow remote and automated control with greater reliability.

FINDINGS: Laboratory tests were carried out to determine the performance characteristics of sprinkler heads and solenoid valves when subject to rapid pulsing. Previous tests had shown that the shape of the water distribution patterns with either smooth or grooved deflector pads are minimally affected by pulse irrigation. The tests were mainly designed to evaluate the flow control performance of different brands of solenoid valves.

Several important characteristics were measured. First, the **averaged discharge** depends on the effective opening and closing time of the valve. In the case of pilot operated valves, the time it stays open is longer than the time the valve is energized. The pilot operated valves use the pressure in the line for operation and requires a certain time to open and close. As a consequence, the averaged discharge increases with the pulse frequency and for high frequencies it can be much higher than the one calculated from the duty cycle of the activating signal alone, especially for slow closing valves. Since, the consistency of the opening and closing times between multiple valves is important to obtain uniform applications in the field, several valves of each brand were tested. It was found that the averaged discharge variance among valves of the same manufacturer increased with the pulse frequency and high frequencies should be avoided to obtain uniform applications. Direct acting solenoids were found to react almost instantaneously, such that the volume of water delivered is

directly proportional to the duration of the electrical pulse, at least for pulses of 1 second duration or greater. The second characteristic measured was the **head loss across the valves** for a range of discharges. Two valves of each brand, those with the most different averaged discharges, were tested. It was found that in most cases the valves of the same manufacturer present similar losses for the range of discharges tested and the different performances found in the previous tests could not be caused by variation in head losses. However it was noticed that in the case of pilot operated valves, a minimum pressure drop is required to hold the diaphragm in the opening position and for low discharges the head loss can vary a little. It was also observed that the same valve with different diaphragms have different losses and can be responsible for part of the variations in valve performance. Third, the **life cycle** of one brand of pilot operated valve was measured and it was found to be in the range of 500,000 operations. Since the life cycle of a valve is a function of the number of operations, the use of very high frequencies will increase the maintenance costs of the system.

Water distribution patterns for LEPA heads working in spray mode with both, smooth and grooved deflector pads, were also determined in laboratory tests. The tests were performed under ideal conditions and for different heights above the surface.

In addition to laboratory tests, an existing design and simulation program for center pivots was modified to handle linear move irrigation systems in continuous move.

INTERPRETATION: The tests results provide enough information to start field scale applications of pulse irrigation. It will allow the linear move system to selectively apply the wide range of water and chemical treatments required for research.

FUTURE PLANS: Uniformity of application is an important characteristic of irrigation systems and it is even more important when the system is utilized for research. In the case of moving systems, it depends not only on selection of appropriate nozzle sizes, but also on the start-stop characteristics of the system. It is important to verify the impact caused on uniformity by different combinations of pulsing frequencies and start-stop sequences. The existing simulation program for linear systems will be modified to be able to simulate the application depths obtained when the system is pulsing and moving intermittently. In this way, it will be possible to select the best combination of operating characteristics for the field.

IRRIGATION TECHNOLOGIES FOR SUSTAINABLE FARMING WHICH CONSERVE WATER AND PROTECT WATER QUALITY

Dale F. Heermann, ADODR and Roger E. Smith
Water Management Research Unit

CRIS: 5402-13000-004-04S, SCA 58-5402-1-129

PROBLEM: The ability to improve the management of our irrigation systems to conserve water and protect our water quality requires new integrated systems to allow the user to meet the national goals and at the same time sustain future food and fiber production. One of the greatest opportunities for more economical systems to provide for sustainable agricultural production is the improvement of management of the total agricultural system. Management of the spatial and temporal variation must be included in future production systems to protect our water quality. The use of Geographical Information Systems (GIS) offer the ability to collect, process, store and interpret large data bases characterizing the variability. The appropriate user friendly systems that can process these data and provide useable management recommendations are needed.

APPROACH: The CSU Agronomic Research Farm which is currently being constructed will be used for a case study for the development of a GIS model for integrated management. The first step is to define and collect the data bases necessary for model development. Climatic data, Farming land/land use/land cover, soil type, soil fertility as related to nutrient availability, soil productivity, soil moisture availability, crop acreage, crop treatment, planting dates, crop types, fertilizers used, weeds, pesticides used, and water application history will be part of the needed data base. The management algorithms will be developed with the input from the many disciplines that will be cooperating of research projects on the CSU farm.

It will be necessary to study the different GIS packages available and evaluate their capabilities for meeting the objectives of developing the integrated management system.

FINDINGS: We have installed a government program (GRASS) on our HP UNIX based machine for testing. A data base representing the field site at the CSU farm is nearing completion. It appears that the GRASS GIS program may not be adequate for the planned activities and ARCINFO is being considered for purchase. An experimental program is planned with a graduate student will collect soil data for characterizing the field heterogeneity. Progress in implementing the GIS application has been partially hindered by failure to get a working Xwindows capability.

INTERPRETATION: One graduate student has been digitizing the data from the North Ag Campus and is progressing on plans to develop algorithms for interpreting the data. A second thrust of the project is in the early stages with work just beginning on assembling the tools and data bases. A graduate student has recently joined, who will require considerable initial familiarization, and field data will not be collected until summer.

FUTURE PLANS: The collection of data bases and testing of models for suitability in developing the management models will be conducted in the next year. As the data bases are assembled, the algorithms will be developed for combining the large array of information to provide management useful maps and management recommendations.

STUDY THE PHYSICS AND DEVELOP THEORY OF INFILTRATION FOR IMPROVED IRRIGATION

Dale F. Heermann, ADODR

CRIS: 5402-13000-004-01S, SCA 58-5402-9-106

PROBLEM: Surface irrigation is the method used on about 60% of the total irrigated area. A challenge has been to improve the efficiency of these systems. The infiltration rate of the soil is the controlling factor since it controls the amount of water stored in the root zone. The soil surface is also used as the transmission zone from part of the field to another. The understanding and management of infiltration is important for the design and operation of surface irrigation systems. Surge irrigation is a technique that has been found experimentally to increase the efficiency for surface irrigation. However, the understanding of the physics is not well understood and needs more study.

APPROACH: Field and laboratory studies provided a better understanding of the physics of infiltration. Field studies to measure the compaction from different tillage operations were made. Laboratory studies to run to find the effects of compaction and soil surface sealing. These results will be analyzed with hydraulic models to develop design and operational criteria.

FINDINGS: A surge infiltration model is being developed for improving the management and performance of surge irrigation. Surface sealing, consolidation and air entrapment are the most significant mechanisms which are included in the model. A modification of the Green-Ampt infiltration equation is being made to account for these mechanisms and accomodate changes in hydraulic conductivity, bulk density, porostity and wetting front suction due to surge phenomena. Functional relationships between soil physical parameters and surge mechanisms are being developed. The infiltration models with reduction factor will be incorporated into an existing surface irrigation model.

INTERPRETATION: The model developed will allow simulations of various scenarios to determine the best design and operation criteria for surge irrigation systems. The results of field experiments reported in the literature has had mixed effects on the benefits of surge irrigation. The individual surge effects have been analyzed and studied individually. The model will assist in understanding the interactions of these effects by playing "what if?" trials.

FUTURE PLANS: The specific cooperative agreement was not funded for the next phase and this work will of necessity be discontinued.

UNIFORMITY AND EFFICIENCY OF CHEMICAL APPLICATION THROUGH IRRIGATION SYSTEMS

H.R. Duke, W.C. Bausch, G.W. Buchleiter, D.F. Heermann, and R.E. Smith
Water Management Research Unit

CRIS: 0500-0032-021-00D

PROBLEM: It is imperative for efficient chemical application that irrigation water be applied uniformly and in depths to control leaching; that the chemical be mixed uniformly with the water when applied with the irrigation; that applications be timed for optimum effectiveness; and that the irrigator have the knowledge of variability in soils, crops, and application and the tools to allow him to manage water and chemical application under variable soil, crop, and application conditions.

Self-propelled irrigation systems can apply water and solutions of agricultural chemicals uniformly to growing crops. Studies indicate that "chemigation" can reduce the amount of chemical necessary for pest control when special equipment capable of spraying the underside of leaves is used. Chemigation holds special promise when used with good irrigation water management for minimizing leaching of agricultural chemicals toward the water table.

APPROACH: The linear move sprinkler at CSU-NAC is being modified to allow predetermined differential water and nitrogen fertilizer applications. Cooperative projects have been developed with CSU (Westfall and Cardon) and pursued with other ARS researchers (Follett, Shaffer, Hinkle) to develop field scale research under this linear system to evaluate optimum water/nitrogen management practices. This project will result in systems appropriate for applying nitrogen and water as needed for crop uptake, so as to maintain low levels of water and nitrogen in the soil over the winter period when they are subject to leaching by offseason precipitation.

Geographic Information Systems are being applied to field scale problems to develop methods of providing information to the grower which will allow him to best manage his water and ag chemical applications. Combining topographic information, soil data, irrigation system uniformity and water and chemical transport models will allow evaluation of the effects of management decisions, including economic aspects, when applied to situations where variability of several parameters exists.

Field plots at AERC under the center pivot were planted to corn; four nitrogen treatments were imposed on each of two water treatments. Canopy reflectance in four distinct wavebands was obtained throughout the growing season. Leaf area measurements were taken at least twice per week. Plant samples were obtained at V2, V4, V6, V8(after hail damage), V14, R1, R4 and R6 growth stages for dry matter and N concentration analysis.

FINDINGS: During 1992, Duke, Heermann and Buchleiter have provided frequent oversight inspection of the irrigation system installation at the CSU North Ag Campus north of Fort Collins.

Water distribution data from 60 SCS center pivot tests were used to evaluate the importance of application uniformity on total water and chemical requirements. We demonstrated that the historically acceptable figure of 80% uniformity coefficient will result in significant excess of water or chemical being required if a minimum value is to be applied over the majority of the field. Although perfect uniformity is impossible, improvement of CU from 80% to 95% will reduce the excess application required to meet minimum requirements on the average over the quarter of the field receiving the least water from 47% excess to 9% excess.

Chlorophyll is absorbed in the red region of the electromagnetic spectrum. The TM3 waveband (0.63 - 0.69 μm) of the Exotech radiometer is within this region. Temporal curves of the TM3 ratio of reflectances from the target of interest to a reference target (heavy applied N treatment) showed evidence that N differences in the corn canopy were being tracked.

INTERPRETATION: The need to evaluate the performance of sprinkler irrigation systems is of particular importance when the systems are used for application of chemicals. Further, application of chemicals through the sprinkler system shows promise to reduce leaching of chemicals when compared with conventional application methods. Methods which include environmental responsibility and economics into the management's determination of whether to improve an irrigation sytem provide a useful management tool for development of sustainable agricultural practices.

Because many agricultural chemicals are readily soluble in water, development of water and chemical management programs that provide water and chemical only when, where, and in the amount needed have considerable promise to reduce the impact of agriculture on both the quantity and quality of the Nation's water supplies. Such systems minimize the opportunity for chemical leaching either by excess irrigation or by natural precipitation as well as conserve water resources.

Remote sensing of the nitrogen status by reflectance measurements will allow rapid real-time assessment of plant nitrogen status. If this ratio is correlated with plant N status, then rapid assessment for N fertilizer requirements over large areas is possible in a spoon feeding management scheme. As methodologies for remotely measuring data are developed, they may replace some of the costly calibration required in current models. As newer sensor technology provides the necessary data on a cost effective basis, improved irrigation system controls will be developed to apply chemicals in an environmentally safe way.

FUTURE PLANS: Simultaneously, measurements will be made of canopy reflectance, soil water and N concentration, tissue N concentration, canopy temperature, leaf area index, and light penetration through the canopy. If remote methods of measurement can be correlated with more direct measurements, then rapid assessment methods for large areas may be developed to allow application of nutrients in the most prudent manner.

Upon completion of the plant material N analysis, correlations will be made between plant N concentration and the TM3 reflectances ratio. Correlations with SPAD meter readings taken throughout the growing season will be investigated also to determine the correlation with plant N concentrations. Additional studies are planned for 1993 at the North Ag Campus that cover a broader base of nitrogen treatments and irrigation levels under both sprinkler and surface irrigation in conjunction with ARS and CSU personnel. Reflectance in the blue and green

regions will be considered as well, since the blue region is another chlorophyll absorption region. The green region provides maximum reflectance in the visible light spectrum. A combination of the blue, green and red reflectances may produce an index superior to a single band for estimating plant N status.

INTEGRATED MANAGEMENT SYSTEMS FOR SELF PROPELLED SPRINKLER IRRIGATION SYSTEMS

G. W. Buchleiter, D. F. Heermann, H. R. Duke, R. E. Smith and E. E. Schweizer
Water Management Research Unit

CRIS: 5402-13000-004-02T

PROBLEM: Center pivot irrigation systems are used extensively in the central Great Plains and in the Pacific Northwest. There is a continuing need to improve water management, to minimize environmental damage from overirrigation and to minimize energy costs. The interactions of the various aspects of crop production (e.g. water and nutrient use, weed and pest control) as well as the size and complexity of irrigation systems make it difficult to manage effectively without assistance from a computer. The ability to resolve potentially conflicting crop production practices and to respond quickly to changing operating conditions can enable the producer to improve irrigation practices and reduce production costs.

APPROACH: Producers can improve their management skills by following recommendations obtained from computer models. For successful adoption, models must be easy to use by people with limited computer background. The models must be properly calibrated and resolve potentially conflicting crop production practices so producers are confident of the results and recommendations.

These model programs are integrated with radio telemetry monitor and control systems which automatically collect data and initiate controls for implementing recommendations. Experiments are necessary to test appropriate sensors for obtaining the necessary data and to develop controls for implementing the recommendations. A Cooperative Research And Development Agreement (CRADA) is in place with Valmont Industries and limited technical assistance is provided to our cooperators to improve the transfer of these newly developed technologies.

FINDINGS: Existing base station software was field tested at several locations and is now being marketed by Valmont. Logic was added to the base station software which minimizes false alarms from changing pivot operations and supports additional capabilities of the C.A.M.S. panel. A computerized irrigation scheduling program was interfaced to use irrigation data from the monitor and control program to recommend the time and amount of the next irrigation. The accuracy and reliability of a weather station was evaluated in anticipation of an expanded product line next year.

Base station software was restructured to improve functionality and maintainability and to enable expanded capabilities such as controlling linear move machines. Development of user requirements and design criteria for the base station software to monitor/control linear move machines is underway.

Major irrigation system construction was completed at the CSU North Ag Campus (NAC). Installation included a linear move sprinkler equipped with a computerized C.A.M.S. control panel and radio telemetry to enable monitor and control from the NAC irrigation office. This machine will: (1) irrigate 26 acres of plots and bulk cropped areas, (2) be a major test site for testing and

evaluating base station software and associated management improvement models, and (3) collect machine performance data necessary for computer modeling of self-propelled sprinklers.

A laboratory test stand has been setup at the Agricultural Engineering Research Center (AERC) and initial tests have been conducted to determine the hydraulic characteristics of a new, unique sequential spray irrigation system developed for orchard irrigation. This system shows potential to provide an inexpensive means of applying chemicals at rates as low as 3 gallons per acre when attached to self-propelled irrigation systems.

Our advisory role to a cooperating farm in Oregon which has integrated irrigation scheduling and pump optimization programs with their radio telemetry system, is continuing at a minimal level.

INTERPRETATION: Several companies have introduced new products offering remote monitoring and control indicating increasing interest in this approach for improving management of irrigation systems. Valmont is aggressively marketing these control systems for production agriculture and municipal land application waste disposal sites. The customer's acceptance depends on the direct cost savings, their ability to incorporate the recommendations into their management style, and their ease of use.

The sequential spray irrigation system as adapted to chemical application will eliminate the inherent hazards of conventional chemigation by eliminating the hydraulic connection to the water supply, thus considerably reducing the potential for water contamination by ag chemicals. The system is also readily adaptable to 'spot treatment' under self-propelled sprinklers, a technology which could provide much more effective use of ag chemicals.

FUTURE PLANS: Since the linear move sprinkler machine is intended to serve several different research functions, additional equipment and instrumentation will be installed. A datalogger will record the start-stop sequences of the tower movements to provide data for use in a computer simulation model. The sprinkler will be equipped with LEPA irrigation heads to achieve very uniform applications and minimize wind drift for plot work. To accomplish differential applications, the heads are manifolded in 8 segments along the sprinkler line and individually pulsed so the application depth differs between each segment. The machine will also be equipped with a separate chemical application system, capable of individual control over the same 8 segments. An auxiliary controller will be installed in the machine's control panel which will allow selection of predetermined water and chemical application patterns from the irrigation office.

Since this linear move machine will be the primary test site for the base station software controlling linear move machines and associated management models, numerous reliability and model verification experiments are anticipated. Minimal technical assistance is planned with a cooperator in eastern Colorado to ensure that the irrigation scheduling program is properly integrated with the base station software. Other more detailed models such as **OPUS** which deal with infiltration, runoff, nutrient management, water quality and weed management models can be integrated into the system as additional tools. The level of complexity of these models depends on the quality of the data that can be measured and the ability of the available hardware to implement the necessary controls.

As part of our CRADA with Valmont, the unique, sequential spray irrigation system will be tested in the laboratory and on the linear move sprinkler to determine hydraulic characteristics appropriate to design for chemical application on self-propelled sprinklers.

IRRIGATION SCHEDULING FOR WATER AND CHEMICAL MANAGEMENT

G.W. Buchleiter, H.R. Duke, W.C. Bausch, R.E. Smith and D.F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Concepts of irrigation scheduling by soil water balance from meteorological data have been available for more than two decades. Producers and action agencies such as the Soil Conservation Service (SCS) are realizing that good water management is essential for controlling fertilizer and pesticide leaching. Researchers have developed numerous models for management of irrigation water and nitrogen under irrigated lands. There is a need for consensus on the most appropriate algorithms for inclusion in user-oriented models and for assembling such models, distributing to potential users, and supporting the models once distributed.

APPROACH: Work continues to support the ARS irrigation scheduling program developed by this group. A Colorado weather data base is being developed to make necessary data available to those who wish to use the program.

A model capable of using additional kinds of data for making recommendations on water and nitrogen management at the field level is necessary. A systems engineering approach is being used to evaluate user requirements that have been identified by ARS, SCS, university personnel and producers. Existing models will be studied to determine the most appropriate algorithms from each to meet these needs. Technical aspects of model formulation will be conducted by the ARS and university scientists. SCS Technical Information Services Division (TISD) in Fort Collins will develop input/output formats and will be responsible for distribution and user support for the models in the SCS organization.

FINDINGS: Requests from producers, action agencies, and scientists for the scheduling program continue to be strong. More than 105 copies of the program have been distributed throughout the world during the past 3 years. Direct support was given to several technically oriented farmers throughout the U.S. who are using the programs. Particularly Buchleiter and Duke have responded to numerous requests from Extension, SCS and consultant groups to participate in farmer-oriented water management workshops throughout the Plains. Technology transfer was promoted by assisting SCS and Extension personnel in checking instrument calibration, trouble shooting instruments, and answering questions about operating the program.

Duke cooperated with personnel in CSU's Dept. of Plant Pathology and Weed Science to coordinate procurement and installation of a multiple use weather station network throughout Colorado. The group has installed 22 weather stations, the data from which are used to provide real-time forecasts of pest infestation and crop water use information for irrigation scheduling. The data are collected daily, via hardline or cellular telephone connections, by the microcomputer in Duke's office, and stored on the Water Management network server at AERC. With the assistance of CSU Extension Service and College of Engineering, AERC was connected to the CSU Computer Backbone in 1992, which gives access

to the data to the University Community as well as to other ARS groups and other users having access to INTERNET.

Buchleiter worked cooperatively with SCS TISD personnel to prioritize functional requirements and to select a hydrology model from existing computer models that can be implemented in SCS field offices in 1993. A Soil Water And Nitrogen, SWAN, project was selected as an ARS systems engineering project to meet producer and SCS field office needs on a long term basis. Systems engineers met with SCS National Water Management Team and TISD personnel to begin defining and documenting functional, technology and evaluation requirements.

INTERPRETATION: Producers and action agencies are becoming more concerned about the potential for leaching of agricultural chemicals from improper irrigation management. As water quality concerns grow, irrigators will be required to control the movement of agricultural chemicals into the nation's water supply. One of the primary means of implementing such control is by control of the water, which is the principal means of chemical transport. The availability of programs useable by the irrigator will allow more informed day-to-day decisions regarding management of water. Incorporation of crop growth models and chemical transport models will further enhance the producer's ability to control chemical transport. This cooperative program development represents a major commitment by ARS to support other action agencies within the U.S. Department of Agriculture.

FUTURE PLANS: Limited technical support to SCS and Extension personnel and to producers implementing the current scheduling program will continue. Weather data from the Statewide network will continue to be processed for the short term (through 1994), while assisting CSU Extension and Experiment Station to pursue avenues of obtaining permanent support for the network.

Upon completing the various requirements of the **SWAN** project, **OPUS** and other existing models will be compared to determine which algorithms may be used to meet the defined requirements. A comprehensive soil water data set to be collected at the CSU-North Ag Campus in 1993, will be used as part of this evaluation process. The appropriate algorithms will be integrated in a model and validated.

SCS programmers will be responsible for coding and implementing these models in UNIX environment of their field offices. A similar computer program operating under DOS will be developed for individual producers to use for making water and fertilizer management decisions on a real-time basis. This program could also be implemented as part of an integrated multi-discipline management software package for self-propelled sprinklers.

Cooperative work will continue with the SCS to validate the interim hydrology model that is to be implemented in 1993 within the SCS organization.

APPLICATION RATES, INFILTRATION, RUNOFF AND EROSION IN IRRIGATION

R. E. Smith, H. R. Duke, G. W. Buchleiter, and D. F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Conventional design methods regarding the relationship between application rate and potential runoff under sprinklers are still based on infiltration relations implicitly assuming instantaneously ponded surface conditions or a single rate-independent intake curve. As a result, there is often conflicting evidence as to appropriate action to reduce runoff: that is, should the irrigator apply smaller amounts more frequently (which will result in a wetter soil surface) or large amounts less frequently to allow the surface to dry between irrigations? Design methods should also account for the effects of spatially varying soil properties, redistribution between wetting events, and the occurrence of runoff on total distributional efficiency for a given topography. High application rates under various systems often cause erosion and soil movement both within the field and into tailwater.

Rising energy prices and limited water supplies in some areas encourage the use of low pressure nozzles and LEPA systems to reduce energy costs. Reduced pressures generally mean a smaller application pattern and a higher application rate. Usually this high application rate exceeds the local soil intake capacity causing the potential for runoff, especially on significant slopes. Even under more conventional types of sprinklers, runoff can be a problem, particularly in areas of large slope and heavier soils. Irrigators are expressing an interest in independent control of small sections of the sprinkler as a means of minimizing the effects of soil and topographic variability on runoff or leaching.

APPROACH: Research has treated infiltration estimation and furrow flow simulation, including spatially varying soil properties. Experimental data are being used to characterize the random spatial variations in soil hydraulic characteristics, which are then included in simulation to see what characteristics the field as a whole would exhibit in relation to the statistics of the hydraulic characteristics. In effect, the study asks the question; Are there effective mean soil characteristics that can be deduced from soil samples, and if so how can these be found.

A second study is focused on redistribution of soil water between wetting events, for any soil type. Current analytic infiltration theory does not cover the elongation of the wetting profile between wetting events. Khowledge is also required for the effect in intake rates of initial wetting at rates less than those which can cause runoff. This is a case commonly encountered in rainfall hydrology and under center pivot systems with significant overspray in advance of the arrival of the major sprinkling area.

The objective if this work is a robust infiltration model that will have the capability to simulate most any irrigation scenario on a field with any variety of wetting pattern, and to simulate the resulting location and extent of runoff, if any. Such a model will allow simulation of the effects of surface excess under LEPA systems.

FINDINGS: Studies simulating field-scale water movement for heterogeneous soils showed the expected bias in field scale retention and hydraulic conductivity relations caused by heterogeneity. The soil characteristic parameters are found to usually have small asymmetries easily describable by lognormal distributions. A bimodality in distribution of some parameters hints of a mixed pore size distribution not surprising in light of other evidence of "macroporosity". Further, the conceptual and popular similar media theory was shown in these field data not to have evidential merit.

Another study demonstrated the role that these same hydraulic parameters play in the long-term agronomic performance of a soil, including plant growth, below-root leaching, and water use efficiency. It was shown that saturated hydraulic conductivity plays a conflicting role: large values favor intake of rainwater, but also favor increased leaching losses (and conversely). Other parameters play conflicting roles as well, but exhibit an apparent mean range in which water retention over the season is optimum. Soil water hysteresis, often the subject of soil physics investigation, plays a truly minor role in long-term plant water availabiliy, and has its only significant effect in processes near the soil surface.

A relatively simple model for redistribution of water between rain pulses or irrigation pulses was developed. It is applicable to a rather wide variety of soil types. Robust numerical methods for a general furrow flow simulation system, in which water input can occur anywhere along the furrow and can move at an arbitrary rate, are being developed. Development of the CSU North Ag Campus in 1992 provides a field scale site for intensive field studies of spatial variability.

Cooperative research with Silsoe College, England, under an EC research grant, has developed in improved erosion model for rilled or furrowed topographies. This model is to incorporate results from European research groups and is to be used in field verification studies throughout Europe.

INTERPRETATION: As the trend to use low pressure sprinkler systems continues, irrigators must be made aware of the tradeoffs involved. Controlling potential runoff is essential not only for reducing energy usage but also for minimizing water quality degradation from erosion and leaching of chemicals.

The ability to simulate realistically how the soil responds to various input patterns and spatial variations is crucial to studying the potential for improved irrigation efficiency and management of chemicals which are applied either with or separately from irrigation. As more complex models are made available to producers or SCS personnel for use in field situations, research may be needed to either (1) agree on methods for obtaining the required parameters from existing readily available databases e.g. SCS soils DB or (2) define and have some agreement within the technical community on which parameters are needed and how they should be measured.

FUTURE PLANS: As the theory of infiltration is improved and refined, field studies are in order to evaluate the applicability of the theory. Cooperative studies with CSU Agronomy (Westfall and Cardon) under both surge irrigation and the linear move sprinkler will be heavily instrumented to determine application, infiltration, and runoff.

Field experiments and mathematical models will be used to evaluate appropriate management schemes for different soils to ameliorate problems of runoff and translocation under sprinkler systems. Initial field studies will focus on characterizing the uniformity or variability of the soil's hydraulic characteristics.

MANAGEMENT DECISIONS AIDED BY REMOTELY SENSED INPUTS

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Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Water, nitrogen, and weed management strategies can benefit from remotely sensed inputs. Irrigation scheduling models utilize reference ET and time dependent crop coefficients to estimate actual crop ET. Crop coefficients used to adjust computed reference ET for a specific crop reflect average crop development rates. Whenever crop growth rates depart from this average rate, the time-driven crop coefficient may be in significant error. Consequently, actual crop ET may be different than estimated which could result in overirrigation.

Nitrogen management via crop spoon feeding has potential for deterring groundwater contamination by nitrates. Various techniques have been developed to determine nitrogen status in plant tissue. However, these techniques are laborious and time consuming. Leaf reflectance at various wavelengths have been correlated to leaf chlorophyll; unfortunately, applications have not been developed to monitor nitrogen status at the plant canopy level.

Groundwater contamination is also caused by excessive herbicide use. Rapid detection and classification of weed species after crop emergence would encourage mapping the weed population for spot application with selective herbicides.

APPROACH: Corn was planted under the center pivot sprinkler at AERC. The area contained eight plots, with two water treatments and four nitrogen fertilizer treatments. Reflectance of the crop/soil scene in four specific wavebands (blue, green, red and near IR) was computed from measurements of reflected and incoming light. Chlorophyll measurements were taken with a SPAD meter. Leaf area was measured to compute leaf area index. Plant samples were taken for dry matter and N analysis at the V2, V4, V6, V8 (after hail damage), V14, R1, R4 and R6 growth stages.

Canopy reflectance data acquired in 1990, 91 and 92 at AERC over corn were used to further investigate the application of the reflectance-based crop coefficient (K_{cr}) in irrigation scheduling. Different drivers for the K_{cr} were investigated. Simulations using the ARS irrigation scheduling program SCHED were run to compare the traditional crop coefficient presently used in SCHED and the K_{cr} to determine differences in estimated crop water use.

A preproposal was written for the IPM special funding program. Objectives were to develop ground sensing technology for weed seedling identification and mapping in commercial corn fields.

FINDINGS: The red waveband is very sensitive to chlorophyll absorption. Leaf reflectance in this waveband is typically small; the greener the leaf the smaller the reflectance. Temporal curves of the red ratio of reflectances from the target of interest to a reference target (heavy applied N treatment) indicated that N differences in the corn canopy were being tracked. A cursory examination of the red reflectances ratio showed good agreement with the chlorophyll meter measurements. Plant N analysis is currently underway.

Fraction of growing degree days (50-86 method) from planting to physiological maturity (blacklayer formation) was used as a driver for the K_{cr}. The uniqueness of the K_{cr} data for each growing season did not lend itself to representation by mathematical functions. Therefore, linear segments were used to form a temporal curve; 95% confidence limits about the mean were utilized to extend the curve from data point to data point. Thus, K_{cr} data are required at least twice per week to adequately represent the basal crop coefficient curve. Simulations showed that accumulated ET from planting to effective cover (LAI = 3) and for the growing season was an average of 39% less (varied from 33 - 45%) and 8% less (varied from 5 - 10%), respectively, using the K_{cr} as opposed to the traditional crop coefficient.

INTERPRETATION: The red reflectances ratio estimates plant nitrogen status at the canopy level in lieu of a point measurement represented by a plant leaf or leaf discs. This technology lends itself to rapid assessment of the spatial variability of plant N status over large areas for N management decisions in a spoon feeding scheme.

The K_{cr} mimics the basal crop coefficient for corn during normal crop development periods. Its main advantage is that it can account for variable crop growth rates and hail damage; the traditional crop coefficient goes astray during these times. Consequently, the K_{cr} is a true representation of the actual crop condition. Assuming reference ET is adequately calculated from measured climatic data and the soil input data is reasonable, estimated crop ET is improved. This means that calculated irrigation depths should be similar to the amount of water removed by the crop from its active root zone.

FUTURE PLANS: Correlations will be made between plant N concentration and the red reflectances ratio. Reflectance in the blue and green wavebands will be considered as well since the blue waveband is another chlorophyll absorption region whereas the green waveband provides maximum leaf reflectance in the visible spectrum. Correlations with SPAD meter readings will be further investigated. Studies to be conducted under the linear move sprinkler and surge-irrigated plots at CSU-North Ag Campus include cooperative studies with Cardon and Westfall (CSU Agronomy) to apply three levels of irrigation and five levels of nitrogen, including 'spoon feeding' to corn plots. Reflectance measurements will be taken throughout the season along with chlorophyll meter readings, plant tissue samples, and soil samples for nitrogen analysis. These data, repeated on the same treatments applied to the same plots in subsequent years will provide a solid database for assessment of the relative accuracy of the various methods of scheduling nitrogen applications for optimum control of groundwater quality degradation.

Conduct field study to acquire a complete data set to determine 'goodness' of modelling crop ET and the soil water balance with the USDA-ARS irrigation scheduling program using the K_{cr} and other published crop coefficients for corn. Crop phenology, leaf area, canopy reflectance and intercepted PAR will be measured throughout the growing season. Crop ET will be measured with Bowen ratio, energy balance instrumentation. Irrigations will be timed based on measured soil matric potential; soil moisture content will be measured with the neutron probe to determine depletions in the crop root zone.

Images of weed seedlings (broadleaf and grass) in corn will be acquired when field scouting is conducted to count and identify the seedlings. These images will be acquired with digital cameras and transferred to the computer for storage and processing at a later date. GPS technology will be used during acquisition of these images to produce maps of the spatial distribution of the weed seedling populations.

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Publications

Bausch, W.C. and Bernard, T.M. 1992. Spatial averaging Bowen ratio system: Description and lysimeter comparison. Transactions of the ASAE. 35:121-128.

Buchleiter, G. W. 1992. Performance of LEPA equipment on center pivot machines. Applied Engineering in Agriculture. 8(5):631-637.

Champion, D.F., Kruse, E.G., Olsen, S.R., and Kincaid, D.C. 1991. Salt movement under level-basin irrigation. Journal of Irrigation and Drainage Engineering, ASCE, 118(5):642-655.

Duke, H.R. 1992. Water temperature fluctuations and effect on irrigation infiltration. Trans of the ASAE 35(1):193-199.

Duke, H.R., Heermann, D.F., and Fraisse, C.W. 1992. Linear move irrigation system for fertilizer management research. Proceedings 1992 Irrigation Assoc. Meeting. New Orleans, LA.

Ferreira, V.A. and Smith, R.E. 1992. Opus: An integrated simulation model for transport of nonpoint-source pollutants at the field scale. Volume II, User Manual. U. S. Department of Agriculture, Agricultural Research Service, ARS-98, 200pp.

Fraisse, C.W., Heermann, D.F. and Duke, H.R. 1992. Modified linear move system for experimental water application. Proc. Intl. Conf. Advances in Planning, Design, and Management of Irrigation Systems as Related to Sustainable Land Use. Leuven, Belgium.

Havis, R.N., Smith, R.E., and Adrian, D.D. 1992. Partitioning solute transport between infiltration and overland flow under rainfall. Water Resources Research 28(10):2569-2580.

Heermann, D.F. and Duke, H.R. 1992. Effective irrigation depth as a function of uniformity. Proc. Intl. Conf. Advances in Planning, Design, and Management of Irrigation Systems as Related to Sustainable Land Use. Leuven, Belgium.

Kruse, E.G. 1991. Discussion of "Rating correction for lateral settlement of Parshall Flumes" by Abt and Staker. Journal of Irrigation and Drainage Engineering, ASCE, 118(2):337-339.

Lybecker, D.W., Schweizer, E.E., and Westra, P. 1992. Reducing herbicide loading in corn with weed management models. Book of Abstr. 203rd Am. Chem. Soc., Part I, ENVR, #310. San Francisco, CA.

Schweizer, E.E., Lybecker, D.W., and Westra, P. 1992. Computer modeling of weed control systems in corn. (Abstr.) Proc. Calif. Weed Contr. Conf. 44:146.

Schweizer, E.E., Lybecker, D.W., and Westra, P. 1992. Alternative tillage systems to control weeds within the corn row. WSSA Abstr. 32:14.

Schweizer, E.E., Lybecker, D.W., Westra, P., and Wiles, L.J. 1992. Bioeconomic Weed Management Models in Crop Production. Int. Crop Sci. Congr. Proc. Ames, IA. July 14-22, 1992.

Smith, R.E. 1992. Simulation experiments on the role of soil hydraulic characteristics in agro-ecosystems. Proceedings, International Congress on Modeling of Agro-ecosystems, Braunschweig, Oct. 5-9.

Smith, R. E. 1992. Opus: An integrated simulation model for transport of nonpoint-source pollutants at the field scale. Volume I, Documentation. U. S. Department of Agriculture, Agricultural Research Service, ARS-98, 120pp.

Smith, R.E., Goodrich, D.C., and Woolhiser, D.A. 1992 Models for variability and microtopography in surface runoff. (Abstr.) EOS, Transaction of the AGU, 73(43):202.

Wiles, L.J., Wilkerson, G.G., Gold, H.J., and Coble, H.D. 1992. Value of information about weed distribution for improving postemergence control decisions. Crop Prot. 11(6):547-554.

Wiles, L.J., Wilkerson, G.G., and Gold, H.J. 1992. Simulating weed scouting and weed control decision making to evaluate scouting plans. Proc. 1992 Winter Simulation Conference. Arlington, VA. 25:1166-1171.

Wiles, L.J., Wilkerson, G.G., and Gold, H.J. 1992. Modeling the uncertainty of weed density estimates to improve postemergence control decisions. WSSA Abstr. 32:85.

Woolhiser, D.A. and Smith, R.E. 1992. Progress and problems in modelling surface runoff. (Abstr.) EOS Transaction of the AGU, 73(43):241.

Yoder, R.E., Freeland, R.S., Wilkerson, J.R., and Duke, H.R. 1992. Data acquisition and control with cellular telephones. ASAE Paper SW92-3548, 1992 Winter Meeting, Amer. Soc. Agrl. Engrs., Nashville, TN.

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